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Development of a Premier Northern River Fishery: Mesilinka River, the Third Year of Fertilization (1996)

G. A. Wilson, G. A. Larkin, K. I. Ashley, P. A. Slaney, R. W. Land, S. Biancolin and P. W. Davidson

March 1999

PWFWCP Report No. 196

The Peace/Williston Fish & Wildlife Compensation Program is a cooperative venture of BC Hydro and the provincial fish and wildlife management agencies, supported by funding from BC Hydro. The Program was established to enhance and protect fish and wildlife resources affected by the construction of the W.A.C. Bennett and Peace Canyon dams on the Peace River, and the subsequent creation of the Williston and Dinosaur Reservoirs.

Peace/Williston Fish and Wildlife Compensation Program, 1011 Fourth Ave. 3rd Floor, Prince George B.C. V2L 3H9

Website: *www.bchydro.bc.ca/environment/initiatives/pwcp/*

This report has been approved by the Peace/Williston Fish and Wildlife Compensation Program Fish Technical Committee.

Citation: G. A. Wilson, G. A. Larkin, K. I. Ashley, P. A. Slaney, R. W. Land, S. Biancolin and P. W. Davidson. March 1999. Development of a premier northern river fishery: Mesilinka River, the third year of fertilization (1996). Peace/Williston Fish and Wildlife Compensation Program, Report No. 196. 24pp plus appendices.

Author(s): Gregory Wilson[1], G. A. Larkin[1], Ken Ashley[2], Pat Slaney[3], Robert W. Land[4], Steve Biancolin[1] and Peter W. Davidson[1]

Address(es):
[1] c/o Fisheries Research and Development Section, British Columbia Ministry of Fisheries, Fisheries Centre, 2204 Main Mall. University of British Columbia, Vancouver, B.C. V6T 1Z4
[2] Fisheries Research and Development Section, British Columbia Ministry of Fisheries, Fisheries Centre, 2204 Main Mall. University of British Columbia, Vancouver, B.C. V6T 1Z4
[3] Watershed Restoration Program, Ministry of Environment, Lands and Parks 2204 Main Mall, University of British Columbia, Vancouver, B.C. V6T 1Z4
[4] Fisheries Research and Development Section, British Columbia Ministry of Fisheries 34345 Yve Rd., Abbotsford, B.C. V2S 4N2

Development of a Premier Northern River Fishery:

Mesilinka River, the Third Year of Fertilization (1996)

by

G. Wilson[1], G.A. Larking[1] K.I. Ashley2, P.A. Slaney3,
R.W. Land[4], S. Biancolin[1] and P. Davidson[1]

1 c/o Fisheries Research and Development Section, British Columbia Ministry of Fisheries, Fisheries Centre, 2204 Main Mall, University of British Columbia, Vancouver, B.C. V6T 1Z4
2 Fisheries Research and Development Section, British Columbia Ministry of Fisheries, Fisheries Centre, 2204 Main Mall, University of British Columbia, Vancouver, B.C. V6T 1Z4
3 Watershed Restoration Program, British Columbia Ministry of Environment, Lands and Parks, Fisheries Centre, 2204 Main Mall, University of British Columbia, Vancouver, B.C. V6T 1Z4
4 Fisheries Research and Development Section, British Columbia Ministry of Fisheries, 34345 Vye Rd., Abbotsford, B.C. V2S 4N2

Fisheries Project Report No. RD 66
British Columbia Ministry of Fisheries

March 1999

105-02327/

ABSTRACT

Wilson, G., G.A. Larkin, K.I. Ashley, P.A. Slaney, R.W. Land, S. Biancolin and P. Davidson. 1999. Development of a premier northern river fishery: Mesilinka River, the third year of fertilization (1996). B.C. Ministry of Environment, Lands and Parks, Fisheries Project Report No. RD66.

The addition of inorganic nutrients to increase fish production in the Mesilinka River, a northern interior river of British Columbia, is being investigated. Increased production of native stocks is desired to both offset negative impacts following the establishment of the Williston Reservoir and to meet increased angling demands for stream fisheries. 1996 was the third of four proposed years of fertilization of the Mesilinka mainstem. Three reaches on the Mesilinka River (an upstream control reach - Blackpine, and two downstream treatment reaches - T1 and T2) and an additional external reference system (the Nation River) were established in 1992 to monitor the effects of added nutrients on stream production. In 1996, inorganic fertilizer was added upstream of each of the two treatment reaches. Actual loading rates of nitrogen (N) and phosphorous (P) were 76 and 70 % of the target loadings of 15 and 5 $\mu g \cdot L^{-1}$, respectively. 1996 was an atypical hydrologic year compared to previous years of the study, with spring runoff being almost a month later than usual. As a result, summer water temperatures were lower than average and may have negatively impact productivity throughout the system. SRP concentrations measured in the Mesilinka River were predominantly at or below the detection limit of 1 $\mu g \cdot L^{-1}$, and may indicate that P was a limiting nutrient in the system throughout 1996. Total organic nitrogen (TON) concentrations measured were below 80 $\mu g \cdot L^{-1}$ in all three reaches of the Mesilinka River throughout the sampling period, and concentrations dipped below the detection limit in mid-August. NO3+NO2-N levels generally decreased from mid-July (10-25 $\mu g \cdot L^{-1}$) to late August (< 10 $\mu g \cdot L^{-1}$). Decreasing N concentrations through the growing season indicate that fertilization of the Mesilinka River may be leading to N co-limitation by the end of the summer. The lack of elevated nutrient concentrations indicates that, by the end of the summer, all of the nutrients offered to the system via fertilization are rapidly incorporated. As compared to 1995, periphyton peak accrual and accrual rates were depressed in the Blackpine (3.1 $mg \cdot m^{-2}$; 0.06 $mg \cdot m^{-2} \cdot day^{-1}$) and T1 reaches of the Mesilinka (21 $mg \cdot m^{-2}$; 0.45 $mg \cdot m^{-2} \cdot day^{-1}$), but modestly elevated in the T2 reach (9.9 $mg \cdot m^{-2}$; 0.21 $mg \cdot m^{-2} \cdot day^{-1}$), and in the Nation River (14.5 $mg \cdot m^{-2}$; 0.35 $mg \cdot m^{-2} \cdot day^{-1}$). The mean biomass of benthic invertebrates collected in sampling baskets during 1996 increased from the Blackpine reach (61 $mg \cdot 0.005\ m^3$) to the T1 reach (95 $mg \cdot 0.005\ m^3$) to the T2 reach (237 $mg \cdot 0.005\ m^3$). Fertilization appears to have the greatest effect on dipterans within the benthic invertebrate community; in the T1 reach, dipteran populations have increased from less than 30% in 1993 to an average of more than 85% in the three fertilization years (1994-1996). No underwater fish surveys could be completed in 1996 due to inclement conditions. Size-at-age of adult populations, determined by angling, indicate that rainbow trout and Arctic grayling weight- and length-at-age fluctuate greatly from year to year. Two hypotheses were proposed after the 1995 fertilization season regarding the different responses of the T1 and T2 reaches to fertilization. A fish density response to fertilization would be characterized by an increase in fish densities and depressed benthic invertebrate biomass due to predation. The reduced invertebrate population would in turn allow standing stocks of periphyton to respond positively with fertilization. A fish growth response to fertilization would be indicated by little change in fish densities, but an increase in invertebrate population. Higher invertebrate abundance would result in better fish growth, and a decrease in standing stocks of periphyton. Limited fish data in 1996 prevents a complete reexamination of these hypotheses. However, periphyton accrual rates in the T1 reach were substantially increased in 1994 and 1995, but have since subsided to modestly above pre-fertilization measures. Invertebrate populations also

demonstrated increases with subsequent reductions. These two observations may indicate that after a rapid response to fertilization by these communities, the fish population has increased sufficiently to only modestly abate periphyton accrual and benthic biomass which both responded positively to fertilization. In the T2 reach, periphyton accrual rates have not responded as rapidly or as distinctly as in the T1 reach. However, the response of the invertebrate population, although belated, has been more pronounced. The delayed response in T2 could be due to N limitation in the reach following fertilization. With further data from 1997, these two hypotheses can be further addressed.

ACKNOWLEDGEMENTS

This program was funded by the Peace/Williston Fish and Wildlife Compensation Program. Field activities in 1996 were carried out by a team including Tom Gratton, Bob Land, Paul Davidson, and Steve Biancolin.

We also acknowledge the following contributions: MELP (Ministry of Environment, Lands and Parks), Frazer Valley Hatchery Staff (Dale Larson, Ken Scheer, Morley Rempel, Larry Mitchell, Steve Arnold, Nick Basok, Barry Kolodychuk, Charlotte Lawson and Kurt Vinge) who spent many hours organizing, cleaning and sorting benthic invertebrate samples; Theresa Godin developed computer spreadsheets for analysis of underwater fish census; and Debbie Aird provided office administration assistance.

Taxonomic identification and enumeration of benthic invertebrates was prepared by Fraser Environmental Services, #16 - 9324 126th Street, Surrey, B.C., V3V 6A4.

Finally, we thank Dr. Art Tautz, Manager, Fisheries Research and Development Section, for his continued support of our endeavors in stream fertilization.

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INTRODUCTION

Indices of nutrients, including conductivity, dissolved solids and alkalinity, have been reported as positively correlated with salmonid abundance in streams (McFadden and Cooper 1962; Egglishaw 1968). Despite this, inorganic fertilization of streams, as a means to increase the invertebrate food supply to enhance growth and abundance of salmonids in oligotrophic waters, has received only limited attention as a potential habitat restoration, enhancement or mitigation technique (Hall and Baker 1982). This neglect may arise from confusion about the role of allochthonous and autochthonous energy flow in forested stream ecosystems (Johnston *et al.* 1990), regardless of strong evidence that primary production drives food chains in larger streams (Minshall 1978). Also, perhaps a tarnished history of pollution from cultural eutrophication and contaminated waters (Hynes 1971) delayed research on nutrient limitation of the productivity of stream ecosystems, in spite of a very early study by Huntsman (1948), that suggested inorganic fertilization could increase salmonid production by stimulating aquatic insect growth.

Food abundance functions through territory size as a determinant factor affecting the abundance and growth of salmonids, and thus the carrying capacity of streams. Additions of inorganic nutrients to oligotrophic streams increases periphytic production at the base of the food chain (Stockner and Shortreed 1978; Peterson *et al.* 1985; Perrin *et al.* 1987). This in turn can increase insect growth and abundance (Milbrink and Holmgren 1981; Peterson *et al.* 1985; Johnston *et al.* 1990; Mundie *et al.* 1991), and thus the growth of steelhead trout *(Oncorhynchus mykiss),* coho salmon *(O. kisutch;* Slaney *et al.* 1986; Johnston *et al.* 1990), and Arctic grayling *(Thymallus arcticus;* Deegan and Peterson 1992). As such, controlled seasonal increases in nutrient concentrations, which can be easily controlled and readily reversed, should be beneficial to fish production in oligotrophic streams, similar to the routine fertilization of salmon nursery lakes to enhance commercially important sockeye salmon in British Columbia and Alaska (e.g., Hyatt and Stockner 1985).

The use of nutrients to maintain or enhance fish stocks may be a more effective and ecologically sound technique than the introduction of non-native species; the introduction of non-native fishes in freshwaters has likely resulted in a greater loss in biodiversity than any other anthropogenic stress (Schindler 1990). Non-native invertebrate species introduction (intended as a food resource; e.g., mysids) has had unpredictable and disastrous ecosystem effects, and sometimes achieved results exactly opposite of what was intended (Ashley and Thompson 1993). While species introductions proceed largely unregulated after stocking, nutrient additions can be carefully regulated such that species biomass changes but not species richness (Milbrink and Holmgren 1981; Peterson *et al.* 1993), thus maintaining biodiversity (Quamme 1994).

Research has been conducted on stream fertilization for over a decade on Vancouver Island, British Columbia, firstly at the Keogh River during the 1980s (Slaney *et al.* 1986), and then recently at the Salmon River (Johnston *et al.* 1990), Big Silver Creek (Toth *et al.* 1993, 1996a, 1996b) and the Adam River (Slaney *et al.* 1993; Toth *et al.* 1997a, 1997b; Wilson *et al.* 1997). The primary objective of these studies was to establish the effect of nutrient additions on the growth and abundance of anadromous salmonids in oligotrophic streams, and determine if controlled seasonal enrichments are a cost-effective enhancement or restoration technique. A more recent focus of fertilization work has been as a possible mitigation technique for logging impacts on overwinter survival of juvenile steelhead (Salmon River).

The purpose of the Mesilinka River Fertilization Experiment was to determine whether fertilization is a suitable technique to increase production of native fish species, especially Arctic grayling *(T. arcticus)*, bull trout *(Salvelinus confluentus)*, and rainbow trout *(O. mykiss)*, within the Williston Reservoir watershed. Nutrient levels in the Mesilinka are extremely low indicating that the river and its main tributaries are highly oligotrophic. Also, a large portion of the riverine habitat of the Rocky Mountain Trench was lost with the creation of the Williston Reservoir behind the W.A.C. Bennett dam in 1968-70 (Blackman 1992). Critical over-wintering refuges and foraging zones were lost, especially for highly migratory species such as Arctic grayling and bull trout in this large watershed. Lacustrine fish species currently dominate catches within the reservoir while riverine species, such as grayling and mountain whitefish, have declined significantly following impoundment. Therefore, increased grayling production through river fertilization may partially offset the loss in grayling stocks from habitat loss. User surveys within the Williston watershed indicate that angling preference favours rivers over small lakes, and especially over the reservoir (B.C. Hydro 1990). Decreased riverine habitats from impoundment will thus be subject to increased angling pressure. Furthermore, stream fisheries are sensitive to overharvest and decreased quality following increased angling pressure (Slaney 1986). Therefore, river fertilization may develop destination fisheries that can support increased angling pressure while alleviating pressure on other unfertilized systems within the watershed.

A sampling program has been conducted on three reaches of the Mesilinka River, several key nursery tributaries, and the Nation River since 1992. The first two years of this study (1992-93) obtained baseline (pre-fertilization) measurements on discharge, temperature, nutrients, periphyton, invertebrates, and fish communities. Mainstem fertilization began in 1994, and field sampling regimes have been conducted annually to assess both chemical and biological responses. The Nation River has been concurrently but less intensively sampled to serve as an external reference system. This report documents methods and results for the 1996 field season, the third year of fertilization.

BACKGROUND AND STUDY AREA

Peace/Williston Fish and Wildlife Compensation Program

Establishment of the Williston Reservoir in 1968-1972 flooded substantial portions of area rivers, resulting in the loss of riverine habitats utilized by salmonids, Arctic grayling and mountain whitefish. The present Mesilinka project is one mitigation option to compensate for loss of fish habitat. Consistent with angler demand, the Peace/Williston Fish and Wildlife Compensation Program places primary emphasis on enhancement of streams and small lakes by means of pilot projects coupled with evaluations. The fish component of the Peace/Williston Fish and Wildlife Compensation Program operates on the basis of a notional fund, of which only the annual interest is utilized to deliver program goals. In this way, funding and program continuance may be possible in perpetuity.

Mesilinka River and Tributaries

The Mesilinka is a large northern river located 280 km north of Prince George, British Columbia (Fig. 1). The headwaters originate in the Omineca mountain range and the river flows for a distance of approximately 120km to Williston Reservoir. Williston Reservoir was formed behind the W.A.C.

Bennett Dam during the 1960s to provide hydroelectric energy, and is part of the Peace-Slave-MacKenzie river system which ultimately flows north and discharges into the Arctic Ocean.

The mid- to lower portion of the Mesilinka River was used to examine the effects of fertilization (Fig. 2). This section was chosen because (1) temperatures are warmer than upper reaches, (2) nitrogen (N) may not be as limiting in the lower portions due to groundwater input of N, and (3) the lower portion has several road access points making it more suitable for fertilizer delivery (Koning *et al.* 1995). Three study reaches in the mid- to lower river were established in 1992, and maintained in subsequent years to facilitate a before and after unreplicated experiment (Stewart-Oaten *et al.* 1986). A control reach (Blackpine) was located approximately 30 km and 60 km upstream of the upper treatment reach (T1) and lower treatment reach (T2), respectively.

Several tributaries flow into the mid to lower portion of the Mesilinka River. A number of these tributaries provide rearing habitat for juvenile rainbow trout, bull trout, and mountain whitefish (Koning *et al.* 1995). Five tributaries (Carina, Control, Culvert, Fatfish and Gopherhole creeks) in the vicinity of the two treatment reaches have also been studied to assess their rearing potential for juvenile fish. Two of these creeks (Culvert and Gopherhole) were fertilized in 1993 with liquid fertilizer and in 1995 with slow release fertilizer briquettes to assess whether fertilization could enhance juvenile growth and recruitment.

Wild rainbow trout *(O. mykiss)*, Arctic grayling *(T. arcticus)* and mountain whitefish *(Prosopium •williamsoni)* populations inhabit the Mesilinka River, as well as smaller populations of bull trout *(S. confluentus)*. Aside from bull trout, adult salmonid fish are small in size (mean < 30 cm). Salmonid spawning and rearing habitat is found primarily in tributaries of the Mesilinka River and these include Control, Culvert, Carina, Gopherhole, Tutizzi (also known as Tutizika) and Fatfish creeks. There are no known fish barriers to salmonid fishes on the mainstem. Other species found either in the mainstem or tributaries include burbot *(Lota lota)*, sucker species *(Catostomus sp.)*, sculpin species *(Cottus sp.)*, and various Cyprinids including northern squawfish *(Ptychocheilus oregonensis)*.

Forests within the Mesilinka watershed (area 3,285 km^2) include valley-bottom old growth sub-boreal spruce *(Picea sp.)*, boreal white spruce *(Picea glauca)* and black spruce *(Picea mariana)*, and mid-elevation old growth Engelmann spruce *(Picea engelmannii)* and subalpine fir *(Abies lasiocarpa)*. Logging has been active in the watershed since the early 1970s, with harvesting primarily of white spruce, lodgepole pine *(Pinus contorta)* and subalpine fir. Mature white and black spruce, aspen *(Populus tremuloides)*, balsam poplar *(Populus balsamifera)*, willow species *(Salix sp.)*, and red alder *(Ainus rubra)* are the dominant trees and shrubs in the riparian zone. Most activity has occurred in the lower watershed where approximately 30-35% of the area has been logged. In the upper portion of the Mesilinka watershed, only 5% has been logged (J. Thomas, Chief Forester, Finlay Forest Industries Inc., Mackenzie, B.C., pers. comm.). The extent of these impacts in the Mesilinka watershed are undocumented, but past logging to the streambank of some of the tributaries and within sections of the mainstem has likely been detrimental to fish habitat.

Nation River

The Nation River is located approximately 100 km south of the Mesilinka River and also flows southeast into Williston Reservoir, draining a watershed of 5,880 km2. The river is headed by a chain of five large lakes (the Nation lakes) that are situated at the southern end of the Omineca mountains (Fig. 1). Mean

summer water temperatures and flow rates in the Nation are higher than the Mesilinka River (Koning *et al.* 1995), and the Nation tends to be limited in nitrogen as well as phosphorus. The Nation River was not chosen as a primary fertilization target because the higher flow rates coupled with nitrogen-limitation would necessitate larger (more costly) amounts of fertilizer than required for the Mesilinka River. Also, the Mesilinka River was more typical of the cool streams within the Williston Basin. If fertilization of the Mesilinka River produced the desired results in a cost-effective manner, the Nation River would be a candidate for subsequent fertilization in the Peace/Williston Fish and Wildlife Compensation Program.

METHODS AND MATERIALS

Methods utilized in 1996 were consistent with those followed in previous years for the Mesilinka River (Koning *et al.* 1995; Paul *et al.* 1996, 1998). Mesilinka Fertilization Project methods are similar to those of other fertilization projects conducted by the Fisheries Research and Development Section of the B.C. Ministry of Environment, Lands and Parks, such as on the Adam River (Slaney *et al.* 1993; Toth *et al.* 1997a, 1997b; Wilson *et al.* 1997) and Big Silver Creek (Toth *et al.* 1993, 1996a, 1996b).

Hydrology

Mesilinka River discharges in 1996 were obtained from the Water Survey of Canada (WSC) for station 07EC003 located upstream of Gopherhole Creek. Nation River discharges were obtained for WSC station 07ED003, located near its mouth. The Mesilinka River on-site discharge, used to calibrate fertilizer drip rates, was determined using a stage-discharge relationship established with 1993-94 WSC flow data and a staff gauge located at the Blackpine station (Paul *et al.* 1996).

Stream discharge was determined for Carina, Control, Culvert, Fatfish, and Gopherhole creeks from water level gauges installed near the mouth of each tributary and associated stage-discharge relationships. In addition, instream discharge was calculated by summing discharge from subsections of the stream's cross section; discharges for each section were determined as the cell depth x cell width x current velocity (as determined by a Marsh-McBirney current meter).

Water Temperatures

To aid in the assessment of salmonid growth potential in the Mesilinka system, water temperatures were measured in the mainstem and tributaries during the 1996 growing season. Onset Instruments Stowaway miniature data loggers were used in the mainstem control reach (Blackpine), and below the T2 reach at Gratton's camp. Temperatures in Carina, Control, Fatfish and Golpherhole creeks with were also monitored with Onset Stowaway loggers, located at the water chemistry sites near the mouth of each creek. Daily maximum, minimum and average temperatures were calculated from the data records from the loggers (which recorded temperature every 2 h). Langston (1993-96) provides annual data reports on Mesilinka system water temperatures. Nation River temperatures were measured with Ryan TempMentors.

Fertilization

Mesilinka Mainstem

Fertilization of the Mesilinka River was conducted according to the same protocols as in 1994 and 1995, with solutions of phosphorus (ammonium polyphosphate; 10-34-0; % by weight $N\text{-}P_2O_5\text{-}K_2O$) and nitrogen (urea-ammonium nitrate; 28-0-0) based fertilizers metered into the mainstem. The fertilizers were stored in individual tanks, and dripped into the river through separate valve systems (see Larkin *et al.* 1997 for a review of liquid fertilization technologies). On each site visit (3-4 days apart), river discharge was estimated from the Blackpine staff gauge and the established stage-discharge relationship. Fertilizer drip rates were adjusted manually according to current flow conditions to increase downstream phosphorus and nitrogen concentrations by 5 $\mu g \cdot L^{-1}$ and 15 $\mu g \cdot L^{-1}$, respectively. The drip rates both on arrival at the site and after adjustment were recorded and used to calculate fertilizer loading to the river. Drip rates were calculated from the mean of three volumetric measurements of fertilizer taken over 2 min. Table 1 summarizes fertilizer additions to the Mesilinka mainstem during the project.

Table 1. History of fertilizer additions to the Mesilinka River mainstem

Year	Application start date	Reach	Fertilizer type added
1994	June 28	T1	liquid 10-34-0 and 28-0-0
	June 28	T2	liquid 10-34-0 only
1995	June 27	T1	liquid 10-34-0 and 28-0-0
	June 27	T2	liquid 10-34-0 and 28-0-0
1996	July 5	T1	liquid 10-34-0 and 28-0-0
	July 5	T2	liquid 10-34-0 and 28-0-0

Mesilinka Tributaries

Culvert and Gopherhole creeks were initially fertilized in 1993 with liquid phosphorus (ammonium polyphosphate; 10-34-0; % by weight $N\text{-}P_2O_5\text{-}K_2O$) based fertilizer. The fertilizer was added from tanks located 4-5 km upstream from the mouth of each creek, and dripped into the creeks through hose and valve systems. Metering of the fertilizer to maintain nitrogen and phosphorus at target concentrations proved too difficult due to the small flows associated with these streams (Koning *et al.* 1994), and therefore did not continue in 1994. In 1995, fertilization of these tributaries was carried out using solid 'slow release' fertilizer briquettes (7-40-0; % by weight $MgNH_4\text{-}PO_4\text{-}H_2O$) designed to dissolve gradually throughout the summer. Based on the nutrient content of the briquettes, the amount of potential growing season, the previously determined flow regimes and nutrient limitations of each stream, Culvert Creek received 149 kg and Golpherhole received 111 kg. In each stream, the fertilizer was distributed approximately 4-5 km upstream from its confluence with the Mesilinka River, in riffle areas of approximately 40-50 cm depth. A full report of this experimental product can be found in Mouldey and Ashley (1996). Table 2 summarizes fertilizer additions to Mesilinka tributaries.

Table 2. History of fertilizer additions to Mesilinka River tributaries

Year	Tributary	Application start date	Fertilizer type added
1993	Culvert	July 8	liquid 10-34-0 only
	Gopherhole	July 8	liquid 10-34-0 only
1995	Culvert	June 10	slow release briquettes
	Gopherhole	June 10	slow release briquettes

Water Chemistry

Dissolved nutrients were monitored in the Mesilinka system during the 1996 growing season to determine nutrient loading from the tributaries and nutrient changes in the mainstem in response to fertilizer applications. As in previous years, samples were collected biweekly to monthly from each of the mainstem reaches, as well as from Carina, Control, Culvert, Fatfish, and Golpherhole creeks, and the Nation River. Diurnal samples (samples collected at 4 h intervals over a 24 h period) were also collected at the Gratton's Camp site on August 18, 1996.

All water chemistry samples were collected and processed as described by Perrin *et al.* (1987). Samples collected were immediately placed on ice in a cooler and transported within two days to Zenon Environmental Laboratories in Burnaby, B.C., or the Pacific Environmental Science Center (PESC) in North Vancouver, B.C.. Standard methods of analysis as described in APHA (1992) were conducted to determine soluble reactive phosphorus (SRP), total dissolved phosphorous (TDP), nitrate and nitrite-nitrogen (NO_3+NO_2-N), ammonia-nitrogen (NH_3-N), and total organic nitrogen (TON) concentrations.

Periphyton Accrual

As a measure of primary production, periphyton accrual on an artificial substrate was measured in Mesilinka mainstem reaches, tributaries, and the Nation River. The assessments were conducted by attaching a white styrofoam block (19 cm x 39 cm x 1.25 or 0.075 cm) to a concrete block and placing both (styrofoam side up) in 25-40 cm of water with a moderate velocity (15-30 $cm \cdot sec^{-1}$), as described in Perrin *et al.* (1987). As water levels varied, blocks were moved to ensure they were neither washed away nor left dry. Replicate cores (5.7 cm^2 each) of styrofoam substrata were extracted from each block, at approximately biweekly intervals, and placed in plastic vials. The vials were wrapped in aluminum foil to exclude light, then stored on ice in a cooler for transportation until their extraction with 90% acetone and spectrophotometric determination of chlorophyll *a* (Strickland and Parsons 1972). The chlorophyll *a* value for each site was determined as the mean value from replicate samples. Periphyton accrual rates in each reach were calculated by dividing the peak chlorophyll *a* concentrations recorded during each incubation period by the number days that the periphyton block had spent in the stream.

Benthic Invertebrates

The response of aquatic invertebrates to fertilization was assessed by measuring colonization in artificial substrates (Slaney and Ward 1993). The artificial substrate consisted of a cylindrical plastic basket (22 cm diam.; 13 cm depth; 0.005 m^3 volume) filled with 1-3 cm diameter clean gravel. During the 1996 growing season, groups of baskets were placed in the Nation River and in the Blackpine, T1, and T2

reaches of the Mesilinka mainstem. Baskets were placed in approximately 40 cm of water, surrounded by cobbles, and left to colonize with invertebrates for six weeks (baskets were occasionally moved to deeper water as the rivers receded). The baskets were removed using a Surber sampler (0.15 mm mesh net) with invertebrates and detritus collected and fixed in 10% formalin followed by preservation in 80% ethanol (as in 1993-94), or placed directly in ethanol. All samples were taken to the Ministry of Environment research facility at the Fraser Valley Trout Hatchery where they were stained with Rose Bengali, and all invertebrates separated from detritus with the aid of a 10X-dissection microscope. After the samples were blotted and allowed to air dry for 2-3 min to remove excess preservative, total wet-weight of invertebrates in each basket was determined with an electronic balance. Invertebrates collected were also identified to the lowest taxonomic group feasible to determine if nutrient addition has caused any shift in population composition.

Estimated Fish Growth, Abundance and Size Distribution

Adults

Fish were sampled and tagged from the three reaches of the mainstem Mesilinka River in July and August using standard angling techniques with barbless hooks. Weight, fork length, tag colour, tag number, location and condition of fish at release were recorded for all angled fish. Scale samples (fin rays from bull trout) to determine age were taken, processed, and read as described in Ward and Slaney (1988). Fish >20 cm in fork length were tagged at the base of the dorsal fin with Floy tags. Fish tagged in July were given blue tags, and fish tagged in the first two weeks of August were given tags colour-coded to the reach from which they were captured (Blackpine - green/yellow; T1 - orange/white; T2 - blue/white; Table 3 summarizes floy tag colours used throughout the project). The purpose of the different coloured tags in August was to facilitate mark-recapture population estimation. All tags facilitated growth estimation upon recapture. Angling was also conducted in the Nation River during July, with species, weight, fork length, and capture location recorded, and scale samples taken for each fish caught.

Table 3. Floy-tag colors used in mark/recapture population estimates in the Mesilinka River, 1993-1996

	Reach		
	Blackpine	T1	T2
1993	Pink	Yellow	White
1994	Green	Orange	Red
1995	Blue/white	Green/yellow	Orange/white
1996	Green/yellow	Orange/white	Blue/white

Peterson mark-recapture estimates of fish population were successfully completed in 1992-1995, employing standardized underwater fish counts as the recapture phase (recapture by observation). Duplicate underwater counts were carried out within each reach by groups of six divers equipped with dry suits and snorkel gear, using standardized methods described in Gardiner (1984) and Slaney and Martin (1987). Accuracy of underwater counts have been well tested elsewhere, and provided temperatures are >10 °C, the technique provides a reliable assessment of fish abundance in rivers with water clarity >2 m (Slaney and Martin 1987; Rogers *et al.* 1992). All counts at the Mesilinka River were conducted later in the day

(typically 1100-1600 h) when temperatures were 12-14 °C, and when visibility was 3-6 m. Also, a minimum 10 measurements of wetted width were taken within each reach, and swimmers reactive distance (water clarity) was measured during each swim. Swimmers were assigned a lane, and attempted to maintain an equal distance from other swimmers while counting fish to the front and to one side of themselves. The four mid-lane counts were expanded over the mid-channel width, then the shore lane counts were added, to get the expanded results. However, due to inclement conditions, no underwater surveys were completed in 1996. Table 4 summarizes the underwater fish counts conducted during the project.

Table 4. Summary of underwater fish counts conducted in the Mesilinka River, 1992-1996

Year	Swim dates	Reach	Swim distance (km)	No. of swimmers	Mean reactive distance (m)	Mean wetted width (m)	River discharge ($m^3 \cdot s^{-1}$)
1992	Aug. 22, 23	Blackpine	7.5	6	4.2	37.6	23
	Aug. 20, 21	T1	7.2	6	4.0	40.8	26
	Aug. 18, 19	T2	8.1	6	4.0	38.7	27
1993	Aug. 16, 17	Blackpine	7.5	6	3.8	37.6	46
	Aug. 18, 20	T1	7.2	6	4.0	40.8	43
	Aug. 19	T2	8.1	6	4.0	38.7	43
1994	Aug 17, 19	Blackpine	6.5	6	2.3	45.7	43
	Aug. 15, 16	T1	6.5	6	2.5	52.0	47
	Aug. 18	T2	8.0	6	2.0	37.2	42
1995	Aug. 16	Blackpine[a]	7.5	6	2.5	38.5	50
	Aug. 14, 15	T1	7.2	6	3.2	43.0	37
		T2	No swims completed				
1996	No swims completed						

[a] no replicate swim conducted due to inclement weather

Juveniles

Size distribution of juvenile fish from the tributaries (Control, Culvert, and Gopherhole creeks) was obtained from electroshocking suitable rearing habitat in each site. All fish captured (except sculpins) were anaesthetized, measured to the nearest 1 mm, weighed to the nearest 0.1 g on an electronic balance, and inspected for clips before release. Scale samples were taken, processed, and read as described in Ward and Slaney (1988).

Abundance of juveniles was estimated using a Pearson mark-recapture technique. Fish captured by electro-shocking within a 100-200 m section of good rearing habitat (isolated with up and downstream stop nets) had their lengths and weights recorded and were marked with a clip. Marked fish were released back into the stream over the length of the channel shocked, except for the 25 m directly above the downstream net. The recapture phase occurred approximately 2.5 h after releasing the fish and was approximately equal in shocking time to the marking phase. Fish captured were weighted, measured, and inspected for clips. Total salmonid abundance (rainbow trout, bull trout, and mountain whitefish) was calculated using Chapman's modification of the Lincoln-Peterson mark-recapture estimation:

$$\text{Estimated Abundance} = \frac{(M+1)\cdot(C+1)}{(R+1)}$$

where M is the number of individuals marked in the first sample, C is the number of individuals captured in the second sample, and R is the number of recaptures (White *et al.* 1982). The area shocked was calculated by multiplying length between stop nets with mean wetted width, then density determined by dividing total abundance by area shocked. Table 5 summarizes the capture of juveniles in Mesilinka River tributaries throughout the project.

Table 5. Overview of juvenile fish collection in Mesilinka River tributaries, 1992-1996

Year	Tributary	Assessment method
1992	Carina	Traps (June - Sept.)
		Electroshocking (open site, Aug. 21; close site, Sept. 10)
	Control	Traps (June - Sept.)
		Electroshocking (open site, Aug. 20; mark/recapture Sept. 6)
	Culvert	Traps (June - Sept.)
		Electroshocking (open site Aug. 20; mark/recapture Sept. 6)
	Gopherhole	Traps (June - Sept.)
		Electroshocking (open site Aug.; mark/recapture Sept. 6)
	Tutuzzi	Electroshocking (open site, Sept. 7)
1993	Carina	Electroshocking (mark/recapture Sept.)
	Control	Traps (July - Aug.)
		Electroshocking (open site July 18, Aug.; mark/recapture Sept)
	Culvert	Traps (July - Aug.)
		Electroshocking (open site July 7, July 18, Aug.; mark/recapture Sept)
	Gopherhole	Traps (July - Aug.)
		Electroshocking (open site July 7, July 18, Aug. 8; mark/recapture Sept)
	Fatfish	Electroshocking (open site Aug.)
1994	Control	Electroshocking (open site July; mark/recapture Sept. 1)
	Culvert	Electroshocking (open site July; mark/recapture Sept. 3)
	Gopherhole	Electroshocking (open site July; mark/recapture Sept. 1)
1995	Control	Electroshocking (mark/recapture Aug. 11)
	Culvert	Electroshocking (mark/recapture Aug. 12)
	Gopherhole	Electroshocking (mark/recapture Aug. 18)
1996	Control	Electroshocking (mark/recapture Aug. 21)
	Culvert	Electroshocking (mark/recapture Aug. 21)
	Gopherhole	Electroshocking (mark/recapture Aug. 20)

RESULTS AND DISCUSSION

Hydrology

Flow regimes throughout the study area in 1996 were distinct from previous years of the project due to a late spring freshet (Fig. 3). In the Mesilinka River, runoff due to spring snowmelt occurred almost a month later than usual, and continued until the end of August, resulting in the highest summer flows recorded during the project. The mean monthly discharges were 204, 180, 77, and 47 $m^3 \cdot sec^{-1}$, in June through September of 1996, respectively; mean June through September monthly discharges for the Mesilinka River from 1992-95 were 151, 87, 45, and 35 $m^3 \cdot sec^{-1}$.

Spring runoff also occurred later on the Nation River in 1996, resulting in the highest early summer flows recorded during the project (Fig. 3). The majority of the runoff was concentrated in a peak in early June with discharges of over 600 $m^3 \cdot s^{-1}$ recorded. The June through September monthly mean flows were '500 197 70 and 55 m3•sec^{-1}, respectively, and was notably larger than 1992-95 means of 228, 88, 41, and 43 $m^3 \cdot sec^{-1}$.

Mesilinka tributary discharges in 1996 were also some of the highest recorded during the project. Discharges of greater than 8 $m^3 \cdot sec^{-1}$ were recorded in both Carina and Gopherhole creeks; discharges greater than 5 $m^3 \cdot sec^{-1}$ had not been recorded in previous years of the project. Discharges in Control and Culvert creeks were also elevated as compared to previous years. Discharges in Fatfish Creek remained low, below 0.5 $m^3 \cdot sec^{-1}$, but monitoring was only conducted from mid-July through August (Fig. 4).

Water Temperatures

As a consequence of the large and late spring runoff, water temperatures in 1996 were the coldest recorded during the project (Fig. 5). In 1996, Mesilinka River water temperatures recorded (at Blackpine) increased from 6 °C in mid-June to highs of only 10 °C in late-August (July/August 1996 mean = 8.7 °C). Since 1992, water temperatures have tended to increase from 8-9 °C in mid-June, to highs around 13 °C in August, before dropping below 8 °C by the end of September (July/August 1992-95 mean = 11.7 °C). Similar cooler-than-normal temperatures were noted at the Gratton's Camp site. The temperature difference between the Blackpine and Gratton's Camp stations (approx. 62 km apart) in July/August 1996 was the greatest recorded during the project at 1.3 °C, as compared to the *0.4* °C noted from 1992-95 (July/August mean).

Water temperatures were also lower than normal in the Nation River in 1996, where mean temperatures were only 12.7 °C in July and 14.0 °C in August. July and August 1992-95 mean temperatures in the Nation River were 15.9 °C and 15.6 °C (Fig. 5).

Tributary temperatures measured in 1996 were also cooler compared to 1992-95, by an average of 1.1 °C (Fig. 6). Carina Creek, the warmest Mesilinka tributary (lake-headed), had a July/August mean temperature of only 12.8 °C during 1996 as compared to a 1992-95 mean of 14.1 °C. Mean July/August temperatures for Control, Fatfish, and Gopherhole creeks were 6.8 °C, 7.7 °C, and 8.1 °C, respectively in 1996 as compared to 7.6 °C, 9.7 °C and 8.4 °C for 1992-95. No temperature data was collected in Culvert Creek in 1996.

Fertilization

Mesilinka Mainstem

Phosphorous (P) and nitrogen (N) loading at the Roadend Site (Tl) was 3.8 µg $P \cdot L^{-1}$ and 11.2 µg $N \cdot L^{-1}$ in 1996, or 76% and 75% of target concentrations (Fig. 7). Daily loading estimates are unavailable for the Lower Fertilizer Site (T2) for much of the 1996 field season as fertilizer drip rates were not consistently recorded at the start of each site visit. Fertilizer addition at the Roadend site was fluctuated considerably through the addition period, with concentrations rarely approaching 100% of target concentration. Values available for the Lower Site indicate that a large pulse of fertilizer was released

into the Mesilinka in mid-July, and mean fertilizer additions to the river were 3.8 µg $P \cdot L^{-1}$ and 9.6 µg $N \cdot L^{-1}$, or 75% and 64% of target concentrations. Table 6 summarizes fertilizer loading rates throughout the project.

Table 6. Mean daily fertilizer loading rates to the Mesilinka River, 1994-1996

Fertilizer site	Nutrient	Year	Mean loading rate (µg•L^{-1})	% of target concentration[a]
Roadend (T1 reach)	Phosphorous	1994	4.6	92
		1995	3.5	70
		1996	3.8	76
	Nitrogen	1994	9.0	60
		1995	9.9	66
		1996	11.2	75
Lower site (T2 reach)	Phosphorous	1994	3.6	72
		1995	3.2	64
		1996	3.8[b]	76
	Nitrogen	1994	2.4[c]	-
		1995	9.2	61
		1996	9.6[b]	64

[a] target concentrations of 5 µg•L^{-1} P and 15 µg•L^{-1} N

[b] only an estimate as daily loading values not known

[c] 28-0-0 nitrogen fertilizer not added at lower site in 1994

Water Chemistry

Mesilinka Mainstem

Except for the first sample taken at T2 (2 µg•L^{-1}), soluble reactive phosphorus (SRP) concentrations measured in the Mesilinka River in 1996 were all at or below the detection limit of 1 µg•L^{-1} (Fig. 8). However, 1996 water chemistry sampling did not begin until mid-July, and hence the early part of the season cannot be compared with measures from previous years. The SRP concentration profiles resemble those of the pre-fertilization years (1992-1993; Koning *et al.* 1995), and do not reproduce either the large mid-July peak noted in 1994 or the fluctuations in 1995 (Paul *et al.* 1996, 1998). The lack of any substantial concentrations throughout the Mesilinka River may indicate that P was a limiting nutrient in 1996. Nation River SRP concentrations were also low, measured at or less than 1 µg•L^{-1} throughout the sampling period. Figure 9 illustrates total dissolved phosphorous (TDP) concentrations which declined through the summer in all three reaches of the Mesilinka River from a range of 7 - 10 µg•L^{-1} in mid July to below the detection limit 2 µg•L^{-1} in late August. Concentrations in the Nation River declined from 6 µg•L^{-1} in mid July to 4 µg•L^{-1} in late August.

Total organic nitrogen (TON) concentrations measured in the Mesilinka River were below 80 µg•L^{-1} in all three reaches throughout the sampling period, and concentrations dipped below the detection limit in mid-August (Fig. 10). This pattern most closely resembles that observed in 1994, and does not show the fluctuations noted in 1995. TON concentrations were greater in the Nation River, with levels of 160 µg•L^{-1} in mid-July dipping to approximately 100 µg•L^{-1} by mid August; this decreased through the summer mirrored the trends in the Mesilinka River. Concentrations measured in the Nation River in 1996 are consistent with previous years.

With respect to nitrate and nitrite nitrogen (NO_3+NO_2-N), Mesilinka River levels decreased from mid-July to late August, and resemble the concentration profile observed in 1993 and 1994 (Fig. 11). The elevated levels in mid-July in the T2 reach could be a reflection of the pulse of fertilizer introduced at the Lower Fertilization site; however, a large mid-July peak was noted in 1995 and was not consequent to an anomalous pulse of fertilizer (Paul *et al.* 1996). The mid-July peak may also be a reflection of input from tributaries, whose effect would be additive down the course of the river and therefore more evident in the T2 reach than at sites further upstream. Ammonia-nitrogen (NH_3-N) concentrations are illustrated in Figure 12 and were predominantly below 5 $\mu g \cdot L^{-1}$ in 1996.

Decreasing N concentrations through the growing season indicate that fertilization of the Mesilinka River may be leading to N limitation by the end of the summer; pre-fertilization years do not show a corresponding decrease in N concentrations. N levels in the Nation River are commonly below detection limits by early August.

Mesilinka Tributaries

In 1996, SRP concentrations were below the detection limit in all tributaries for the entire sampling period (Fig. 13). Low SRP levels were also noted in 1992; concentrations for 1993 and 1995 are not comparable for Culvert and Gopherhole creeks (below sites) as these tributaries were fertilized. The uniformly low 1996 concentrations suggest that inherent SRP may have been diluted by the large and late spring runoff. TDP concentrations (Fig. 14) generally declined through the summer, with the highest concentration measures in Fatfish Creek at 16 $\mu g \cdot L^{-1}$.

In four of the five Mesilinka tributaries (Control, Culvert, Fatfish and Gopherhole creeks), NO3+NO2-N concentrations noticeably increased over the sampling period, to highs of over 40 $\mu g \cdot L^{-1}$ in both Culvert and Fatfish creeks (Fig. 15). These data do not correspond with the pattern noted in 1995 where concentrations peaked in early July and then decreased (note again that Culvert and Gopherhole sites cannot be compared for 1993 and 1995 due to their fertilization). TON values (determined as total N - inorganic N) generally decreased through the summer in all tributaries, with the highest concentrations detected in Carina and Culvert creeks in July (120 $\mu g \cdot L^{-1}$ and the lowest in Fatfish creek in late August (< 40 $\mu g \cdot L^{-1}$). Limited NH3-N data (Fig. 16) show concentrations declining to a low in early-mid August, then increasing. The late summer increase in N levels seen in both NO_3+NO_2-N and NH_3-N concentrations indicates that P may become the limiting nutrient, toward the end of the growing season.

Periphyton Accrual

Mesilinka Mainstem

Peak periphyton accrual measured in the Blackpine and T1 reaches of the Mesilinka River was low in 1996 as compared to previous years; T2 accruals were comparable with previous years (Table 7). The greatest periphyton accrual was recorded in the T1 reach at 21 $mg \cdot m^{-2}$ (accrual rate 0.45 $mg \cdot m^{-2} \cdot day^{-1}$). Despite this particularly low peak in the T1 reach (as compared to 1994 and 1995), T1 accrual was still 7-fold greater than in the Blackpine control reach (peak accrual 3.1 $mg \cdot m^{-2}$; accrual rate 0.06 $mg \cdot m^{-2} \cdot day^{-1}$). The generally low accrual rates may in part be due to the prevailing high discharges and cold temperatures; reduced periphyton in the Blackpine (control) reach provides support for this hypothesis. However, peak periphyton accrual and accrual rate in the Nation River in 1996 was comparable to

previous years. Reduced periphyton levels in the T1 reach may also be a consequence of fertilization, whereby grazing insects have responded to increased algal production, and reduced periphyton levels to modestly elevated (Perrin *et al.* 1987) or nominal levels (Slaney and Ward 1993).

Table 7. Peak periphyton accrual and accrual rate in the Mesilinka and Nation rivers, 1992-1996

	Peak periphyton accrual ($mg \cdot m^{-2}$)				Peak periphyton accrual rate ($mg \cdot m^{-2} \cdot day^{-1}$)			
Year	Blackpine	T1	T2	Nation	Blackpine	T1	T2	Nation
1992	15.7	12.5	13.3	-	0.23	0.20	0.23	-
1993	7.3	13.0	8.5	13.1	0.13	0.22	0.14	0.28
1994	10.8	127.5	29.7	15.3	0.22	2.60	0.61	0.31
1995	4.4	55.9	4.8	6.0	0.11	1.40	0.12	0.15
1996	3.1	21.0	9.9	14.5	0.06	0.45	0.21	0.35

Mesilinka Tributaries

Peak periphyton accrual and accrual rates measured in 1996 in Meilinka River tributaries were markedly lower than previous years (Table 8). In Carina, Control and Fatfish creeks, accrual rates were 0.06, 0.21 and 0.17 $mg \cdot m^{-2} \cdot day^{-1}$ in 1996 as compared to 1992-95 mean accrual rates of 1.11, 0.44, and 0.61 $mg \cdot m^{-2} \cdot day^{-1}$. As these creeks have not been fertilized to date, the low accrual rates observed in 1996 do not reflect responses to fertilization by grazing insects, but are likely due to the high discharges and low water temperatures. Accrual rates in Culvert and Gopherhole creeks (fertilized in 1993 and 1995) were lower than the two previous unfertilized years (1992 and 1994), and may reflect both lower production due to high discharge and low water temperatures, and a response from the invertebrate community.

Table 8. Peak periphyton accrual and accrual rate in the Mesilinka River tributaries, 1992-1996

	Peak periphyton accrual ($mg \cdot m^{-2}$)					Peak periphyton accrual rate ($mg \cdot m^{-2} \cdot day^{-1}$)				
Year	Carina	Control	Culvert[a]	Fatfish	Gopherhole[a]	Carina	Control	Culvert[a]	Fatfish	Gopherhole[a]
1992	113	23.4	10.8	-	36.0	2.76	0.39	0.28	-	0.59
1993	45.1	39.6	32.9	33.0	37.8	0.5	0.51	0.56	0.66	0.51
1994	39.2	36.8	-	2.6	33.3	0.55	0.53	-	0.09	0.39
1995	32.3	12.7	14.0	56.7	59.9	0.61	0.32	0.58	1.07	1.13
1996	2.8	10.1	4.6	8.2	6.4	0.06	0.21	0.10	0.17	0.29

[a] All Culvert and Gopherhole creek data from lower sites; these creeks were fertilized in 1993 and 1995.

Benthic Invertebrates

Mesilinka Mainstem

The mean biomass of benthic invertebrates collected in sampling baskets during 1996 increased from the Blackpine reach (61 $mg \cdot 0.005\ m^{-3}$) to the T1 reach (95 $mg \cdot 0.005\ m^{-3}$) to the T2 reach (237 $mg \cdot 0.005\ m^{-3}$), and resembled the pattern noted in 1995 (Table 9). Increases in biomass over 1995 levels were greatest in the T2 reach. The Blackpine and T1 data for 1996 should be viewed with caution as on the August 14 sampling visit, the baskets at these two sites were found dry and were thus relocated. Invertebrate biomass measured in the Nation River in 1996 was near identical to that in 1995. Increases

in invertebrate populations over 1995 levels, particularly in the T1 and T2 reaches, may be in response to fertilization (as discussed with respect to periphyton accrual).

Table 9. Mean biomass (wet-weight) of benthic invertebrates (in mg•0.005 m^{-3} ± SE) from the Mesilinka and Nation rivers, 1993-1996

	Mesilinka River							
	Blackpine		T1		T2		Nation River	
Year	Biomass	n	Biomass	n	Biomass	n	Biomass	n
1993	285 (± 47)	10	212 (±56)	10	22 (± 10)	10	498 (± 253)	4
1994	262 (± 72)	10	570 (±273)	10	75 (±25)	9	3147(±431)	6
1995	34(± 5)	10	54 (±17)	8	96 (± 24)	10	63 (± 16)	4
1996	61 (±22)	9	95 (± 27)	10	237 (± 68)	9	64 (± 25)	4

The relative abundance of four taxonomic groups of invertebrates in the Mesilinka River is shown in Figure 17. Taxonomic groups other than dipterans, ephemeropterans, plecopterans and tricopterans are not included as their numerical abundance generally accounted for less than 1% of the total population recovered from the baskets. Fertilization appears to have the greatest effect on dipteran populations. In the T1 reach, dipteran populations have increased from less than 30% in 1993 to an average of more than 85% in the three fertilization years (1994-1996). In *T1*, the dipteran portion of the population increased from 20% in 1993 to over 60% in 1994 and 1995. Relative abundance in 1996 was just over 30%. Relative abundance of dipterans has been relatively unvaried in the Blackpine (control) reach, with a range of 12% (1994) to 36% (1996).

Estimated Fish Abundance, Growth and Size Distribution

Adults

Due to the inclement conditions in 1996, snorkel surveys were not conducted; Tables 10 and 11 summarize data from previous snorkel surveys. In 1996, adult fish population discussion is restricted to growth and size distribution estimates developed from limited angling data. Size-at-age was determined for rainbow trout and Arctic grayling only for three reaches of the Mesilinka mainstem. Processing of Nation River scale samples is currently incomplete. Weight-at-age and length-at-age data for rainbow trout and Arctic grayling angled in 1996 in the Mesilinka River are presented in Figures 18 and 19.

Table 10. Density of fishes (no. per ha) in three reaches of the Mesilinka River as determined from underwater counts, 1992-1996. No counts were conducted in 1996 or in the T2 reach in 1995.

	1992			1993			1994			1995	
	BP	T1	T2	BP	T1	T2	BP	T1	T2	BP	T1
Rainbow trout	0.5	1.5	2.8	1.1	1.9	3.8	1.2	3.4	5.6	0.6	4.9
Bull trout	0.2	0.8	1	0.3	0.5	1.3	0.4	0.8	0.8	0.5	1.3
Arctic grayling	2.6	3.6	2.1	1.4	3	1.7	1.3	2.1	2	2.9	5.2
Mountain whitefish	40	38	9.5	21	14	12	10	27	14	32	98
Suckers	1.9	0.9	5.3	0.4	0.6	2.2	0.1	0.9	4	0.1	0.7
Squawfish	0	0	0	0	0	0.2	0	0	0	0	0

Table 11. Density of size classes of rainbow trout, Arctic grayling, and bull trout (no. per ha) observed in Mesilinka River snorkel surveys, 1992-1996

		Rainbow trout			Arctic grayling			Bull trout		
Reach	Year	20-30 cm	30-40cm	>40cm	20-30 cm	30-40 cm	>40cm	20-30 cm	30-40cm	>40cm
Blackpine	1992	0.24	0.13	0.00	0.56	1.81	0.15	0.00	0.00	0.15
	1993	0.30	0.16	0.00	0.25	1.09	0.09	0.04	0.08	0.10
	1994	0.61	0.40	0.08	0.00	2.01	0.15	0.11	0.02	0.31
	1995	0.37	0.00	0.00	0.23	1.91	0.77	0.00	0.12	0.38
	1996	No swim completed								
T1	1992	0.72	0.67	0.03	1.27	1.90	0.24	0.16	0.30	0.31
	1993	1.01	0.09	0.03	0.87	1.08	0.07	0.07	0.17	0.14
	1994	1.90	0.74	0.21	1.24	1.03	0.11	0.11	0.15	0.57
	1995	2.50	1.14	0.04	1.10	3.05	0.85	0.33	0.56	0.44
	1996	No swim completed								
T1	1992	1.62	0.48	0.00	1.05	0.28	0.02	0.23	0.37	0.34
	1993	1.97	0.49	0.03	0.86	0.23	0.00	0.23	0.43	0.54
	1994	2.05	0.67	0.07	1.17	1.12	0.07	0.28	0.23	0.12
	1995	No swim completed								
	1996	No swim completed								

For rainbow trout, both length-at-age and weight-at-age of 2+ fish decreased from 1995 measures for fish angled in the T2 reach (Tables 12 and 13). No 2+ fish were caught in the T1 or Blackpine reaches. For 3+ fish, weight-at-age measures increased over 1995 in the Blackpine reach, but decreased in both treatment reaches. For 4+ fish, size-at-age increased over 1995 measures in the Blackpine reach. There was an increase in length-at-age but a decrease in weight-at-age from 1995 measures in the T2 reach. No 4+ rainbow trout were angled from the T1 reach in 1996. Over the course of the project, size-at-age measures for rainbow trout in the Mesilinka River have fluctuated considerably.

For Arctic grayling, 3+ fish angled from the T1 and T2 reaches in 1996 were slightly smaller in weight than those in 1995. Fish angled in the Blackpine reach were similar in weight to those angled from the reach in 1994; no 3+ Arctic grayling were caught in the Blackpine reach in 1995. For 4+ fish, mean length-at-age and weight-at-age were greater for fish angled in 1996 as compared to 1995 in both treatment reaches. Fish angled from the Blackpine reach were slightly smaller in 1996 than in 1995. For 5+ fish, size-at-age was reduced in both the Blackpine and T1 reaches as compared to measures from 1995. No 5+ fish were angled from the T2 reach in 1995, but fish from 1996 appear to be substantially larger than those angled in 1994. As was the case for rainbow trout, there has been considerable variation from year to year in the size-at-age of the Arctic grayling population.

Table 12. Mean size-at-age data for rainbow trout from 1992 to 1996 collected from three reaches of the Mesilinka River by angling and electrofishing

		Number of fish					Fork length (mm)					Weight (g)				
Age	Reach	1992	1993	1994	1995	1996	1992	1993	1994	1995	1996	1992	1993	1994	1995	1996
0+	Blackpine		7	2				47	45				1	1		
	T1		6	8	6			51	60	63			1	3	3	
	T2		7	44				42	43				1	1		
1+	Blackpine		2	10				98	106				11	13		
	T1			9	4				108	97				13	10	
	T2		2	6				123	115				25	24		
2+	Blackpine	3	12	5	3		177	160	175	183		66	66	79	63	
	T1	10	9	2	2		162	168	174	190		57	73	84	73	
	T2	10	14	9	21	1	171	146	172	192	172	57	59	81	86	55
3+	Blackpine	21	4	5	11	3	227	201	210	226	225	166	128	130	97	139
	T1	19	4	17	21	2	219	244	229	225	208	131	177	161	132	101
	T2	28	25	25	25	13	207	224	218	245	233	116	130	134	175	151
4+	Blackpine	10	6	2	11	3	281	251	292	258	278	255	208	309	187	261
	T1	6	8	4	17		272	268	275	274		222	230	252	237	
	T2	19	29	15	29	4	254	273	275	286	292	195	214	252	279	258
5+	Blackpine	2	3				326	323				383	378			
	T1	7	5	3	5		316	296	280	315		320	284	258	334	
	T2	7	6	3	1	5	315	294	300	296	308	304	236	308	306	277
6+	Blackpine					2				343	322					360
	T1	2		2	1		315		331			369		386	338	
	T2	4	1			1	311	310			310	355	482			350
7+	Blackpine					1					320					438
	T1															
	T2	1					342					397				

Table 13. Mean size-at-age data for Arctic grayling from 1992 to 1996 collected from three reaches of the Mesilinka River by angling and electrofishing

		Number of fish					Fork length (mm)					Weight (g)				
Age	Reach	1992	1993	1994	1995	1996	1992	1993	1994	1995	1996	1992	1993	1994	1995	1996
0+	Blackpine			1					55					1		
	T1				1					57					2	
	T2			5					73					7		
1+	Blackpine			1					129					129		
	T1															
	T2															
2+	Blackpine		3		1			201		220			114		124	
	T1		5	1	2			177	224	253			91	156	152	
	T2	2	4	1	6	4	198	162	183	223	210	128	57	90	119	94
3+	Blackpine	5	1	1	0	1	269	367	275		292	227	304	276		273
	T1	4	3	2	9	7	268	249	226	269	270	206	189	151	222	213
	T2	14	2	3	8	5	253	270	235	257	261	176	199	166	211	200
4+	Blackpine	19	14	6	18	1	302	298	299	309	298	333	279	346	334	317
	T1	6	5	3	19	8	305	311	286	308	311	317	357	269	342	364
	T2	5	2		4	1	285	283		296	318	255	312		311	353
5+	Blackpine	12	5	4	12	6	328	333	320	345	329	409	352	397	466	428
	T1	5	5	7	9	13	338	326	318	349	336	442	363	397	505	415
	T2	3	1	2	0	2	333	348	313		357	406	511	369		525
6+	Blackpine	6	4		5	3	366	354		336	364	489	483		445	538
	T1	2	3	1	3	7	378	368	369	360	357	554	492	546	557	503
	T2															
7+	Blackpine	3	2	1		2	375	366	365		380	489	482	506		593
	T1	1	1	1		4	360	382	379		373	454	425	606		572
	T2															

Figures 20 and 21 show responses to fertilization in the T1 and T2 reaches presented as differences from the Blackpine (control) reach. Data are only presented for the most abundant species and ages (rainbow trout, 2+, 3+ and 4+; Arctic grayling (ages 3+, 4+, 5+). For rainbow trout, both length-at-age and weight-at-age showed declines in 1996 from 1995 measures. This is particularly noted for weight-at-age of 3+ fish where an increasing trend was developing from data from previous years. The low weights and lengths in 1996 may reflect poor growth conditionsdue to the prevailing cooler water temperatures. Limited 4+ rainbow trout data shows a similar decline in both weight-at-age and length-at-age in 1996 as compared to 1995. Only one 2+ rainbow trout was caught in 1996 (T2 reach), so no information is available for Fig. 20. For Arctic grayling (Fig. 21), both weight-at-age and length-at-age appear to fluctuate greatly from year to year. Limited data for the 3+ age class indicate that fish from the T1 and T2 reaches are consistently smaller than those from the control reach. For the 4+ and 5+ size classes, there was considerable variation from year to year.

Juveniles

As in previous years, bull trout dominated juvenile fish captured by electroshocking in Control, Culvert, and Gopherhole creeks in 1996. Areal density in Gopherhole Creek was reduced from 1995 levels, but comparable with 1994 levels (Table 14). In Culvert and Control creeks, bull trout densities were markedly higher than any other year of the project, particularly in Culvert Creek where areal density was estimated at 99 fish•100 m^{-2}. The fluctuations in bull trout population in Gopherhole and Culvert creeks do not correspond to years when these tributaries were fertilized. Fluctuations of several orders of magnitude in juvenile bull trout populations have been observed elsewhere (Paul and Post 1996) over only a few years. Bull trout catches in 1996 appeared to be dominated by young-of-year cohort, as in 1995 (Paul *et al.* 1996; Fig. 22).

Table 14. Areal density estimates for bull trout in three tributaries of the Mesilinka River determined by mark/recapture, 1992-1996[a]

Tributary	Year	M	C	R	N	Areal Density (#•100 m^2)
Gopherhole	1992	2	3	2	3	1
	1993	10	7	3	21	3
	1994	6	7	1	27	7
	1995	35	26	11	110	20
	1996	29	19	8	67	8
Culvert	1992	9	4	1	24	5
	1993	7	5	2	15	2
	1994	16	7	1	67	5
	1995	35	39	15	89	13
	1996	24	19	4	100	99
Control	1992	13	4	4	13	4
	1993	11	15	2	63	11
	1994	17	9	2	59	8
	1995	2	2	1	3	1
	1996	31	33	10	99	19

[a]population estimates are only unbiased if both of the conditions $(M+C) \geq N$ and $R > 7$ were met

For rainbow trout, areal density in Gopherhole Creek was the lowest measured during the project (Table 15). However, in Culvert Creek, densities were higher than any other year of the project. No rainbow trout were captured in Control Creek in 1996. Only one mountain whitefish was caught in 1996.

Table 15. Areal density estimates for rainbow trout in three tributaries of the Mesilinka River determined by mark/recapture, 1992-1996[a]

Tributary	Year	M	C	R	N	Areal Density (#•100 m^2)
Gopherhole	1992	16	6	4	22	6
	1993	6	5	1	30	3
	1994	0	1	0		
	1995	7	10	2	28	5
	1996	6	3	2	9	1
Culvert	1992	7	9	2	25	5
	1993	3	16	2	21	3
	1994	16	8	4	29	2
	1995	2	3	1	5	1
	1996	8	8	6	12	12
Control	1992	9	10	8	11	3
	1993	6	1	0		
	1994	1	1	1	1	<1
	1995	2	2	1	3	1
	1996	0	0	0		

[a]population estimates are only unbiased if both of the conditions $(M+C) \geq N$ and $R > 7$ were met

CONCLUSIONS

Due to a markedly late spring runoff, 1996 was an atypical hydrologic year in the Mesilinka and Nation River watersheds. Discharge throughout the region was substantially increased over past study years throughout the majority of the growing season. Furthermore, water temperatures were markedly cooler, particularly in the Mesilinka mainstem. Such conditions may have negatively impacted productivity throughout the food chain, from primary production to fish growth. Furthermore, the inclement conditions also impacted monitoring of the response of the river to fertilization.

In the Mesilinka mainstem, SRP concentrations were low throughout most of the sampling period and N concentrations generally declined throughout the summer. These trends indicate that P was a limiting nutrient in the system throughout 1996, with N concentrations possibly becoming co-limiting towards the end of the summer. The lack of elevated nutrient concentrations indicates that all of the nutrients offered to the system via fertilization are rapidly incorporated. In 1996, fertilization of the mainstem was not reflected in periphyton levels, but there was a marked increase in benthic invertebrates, particularly in the T2 reach. A similar increase in the T1 invertebrate population was noted in 1994, but was followed by a net decline over pre-fertilization measures. As has been noted in previous years (Paul *et al.* 1998), the effect of fertilization has been variable between the two treatment reaches.

Paul *et al.* (1998) present two hypotheses regarding the different responses of T1 and T2 to fertilization. A fish density response would be indicated by an increase in density of fish populations following fertilization. This increase would result in increased predation on benthic invertebrates, and subsequently, a lower invertebrate population would permit standing stocks of periphyton to increase. Little change in fish densities, but an increase in invertebrate population would indicate a fish growth response. Higher invertebrate abundance would result in better fish growth, and a decrease in standing stocks of periphyton. Limited fish data in 1996 prevents a complete examination of these hypotheses. However, periphyton accrual rates in the T1 reach demonstrated a response to fertilization in 1994 and 1995, but have since subsided to modestly above pre-fertilization rates. Invertebrate populations also demonstrated an increase with subsequent reduction. These two observations may indicate that after a rapid response to fertilization by these communities, the fish population has increased sufficiently to modestly abate the benthic population which in turn tempers periphyton accrual. In T2, periphyton accrual rates have not responded to fertilization as rapidly or as distinctly as in T1. However, the response of the invertebrate population, although belated, has been more pronounced. The delayed response in T2 could be due to N limitation in the reach following fertilization (Paul *et al.* 1998). With further data from 1997, these two hypotheses can be further addressed.

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Figure 1. The Williston Reservoir Watershed (from Langston 1993).

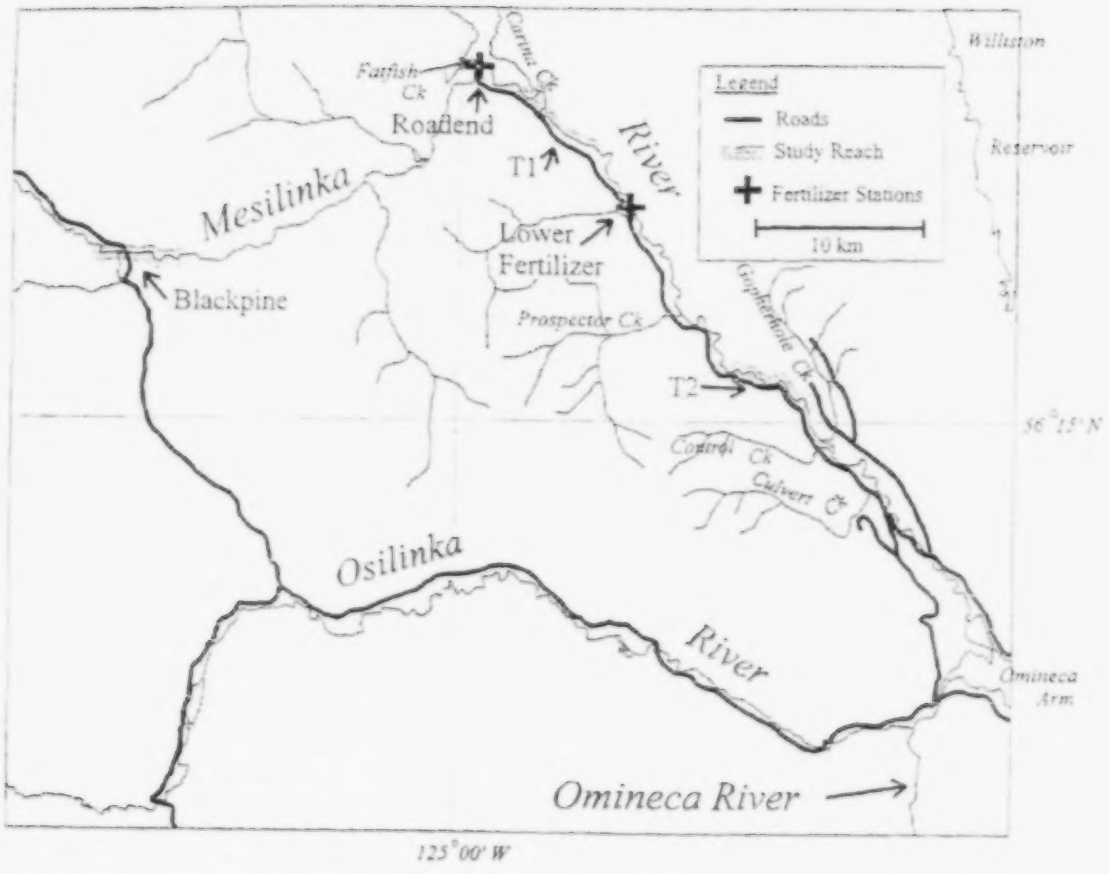

Figure 2. Mid- to lower portion of the Mesilinka River.

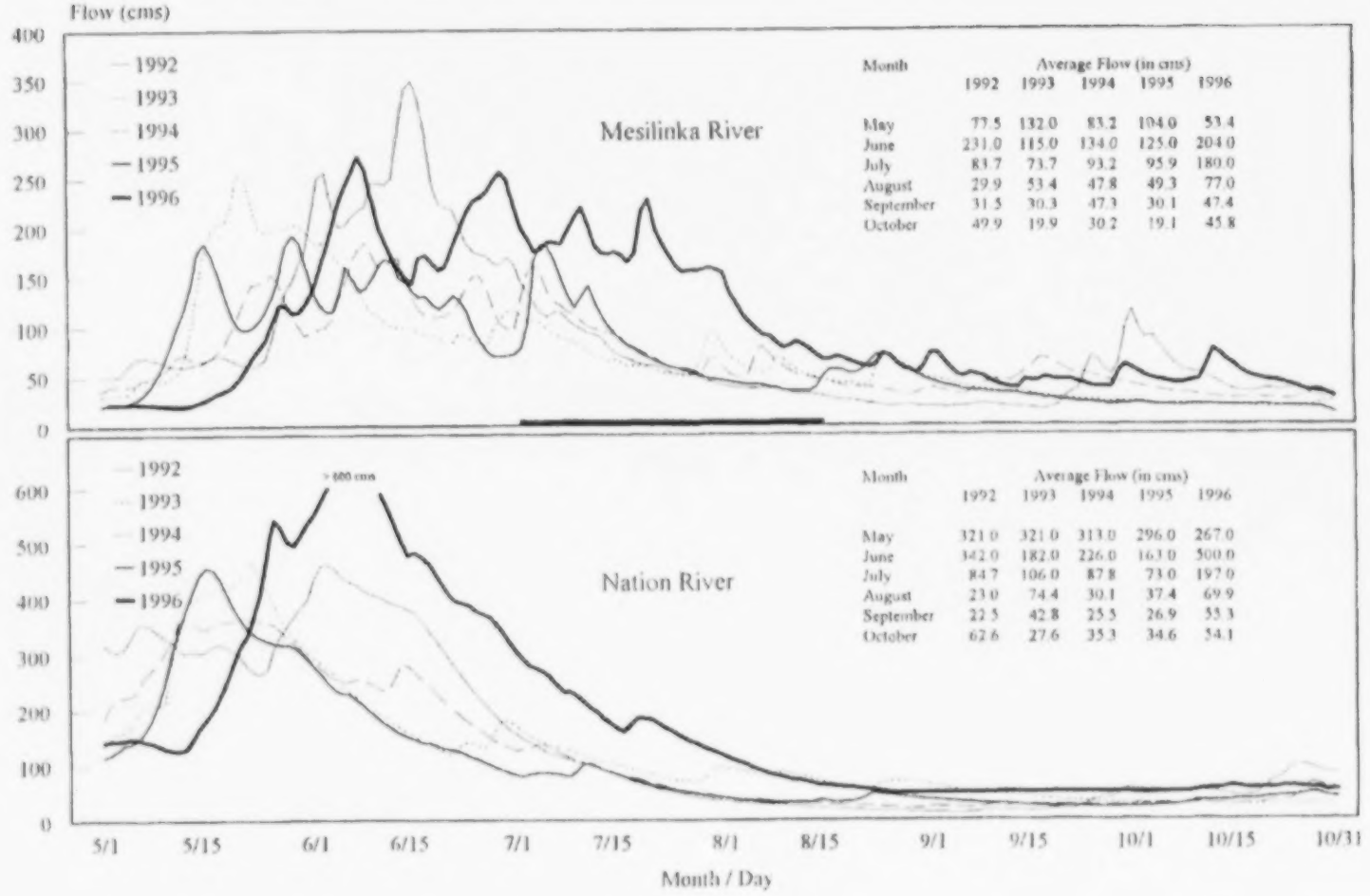

Figure 3. Discharge from the Mesilinka and Nation rivers between May and October, 1992-1996. Dark line on the x-axis of the Mesilinka discharge graph indicates time of 1996 liquid fertilizer addition.

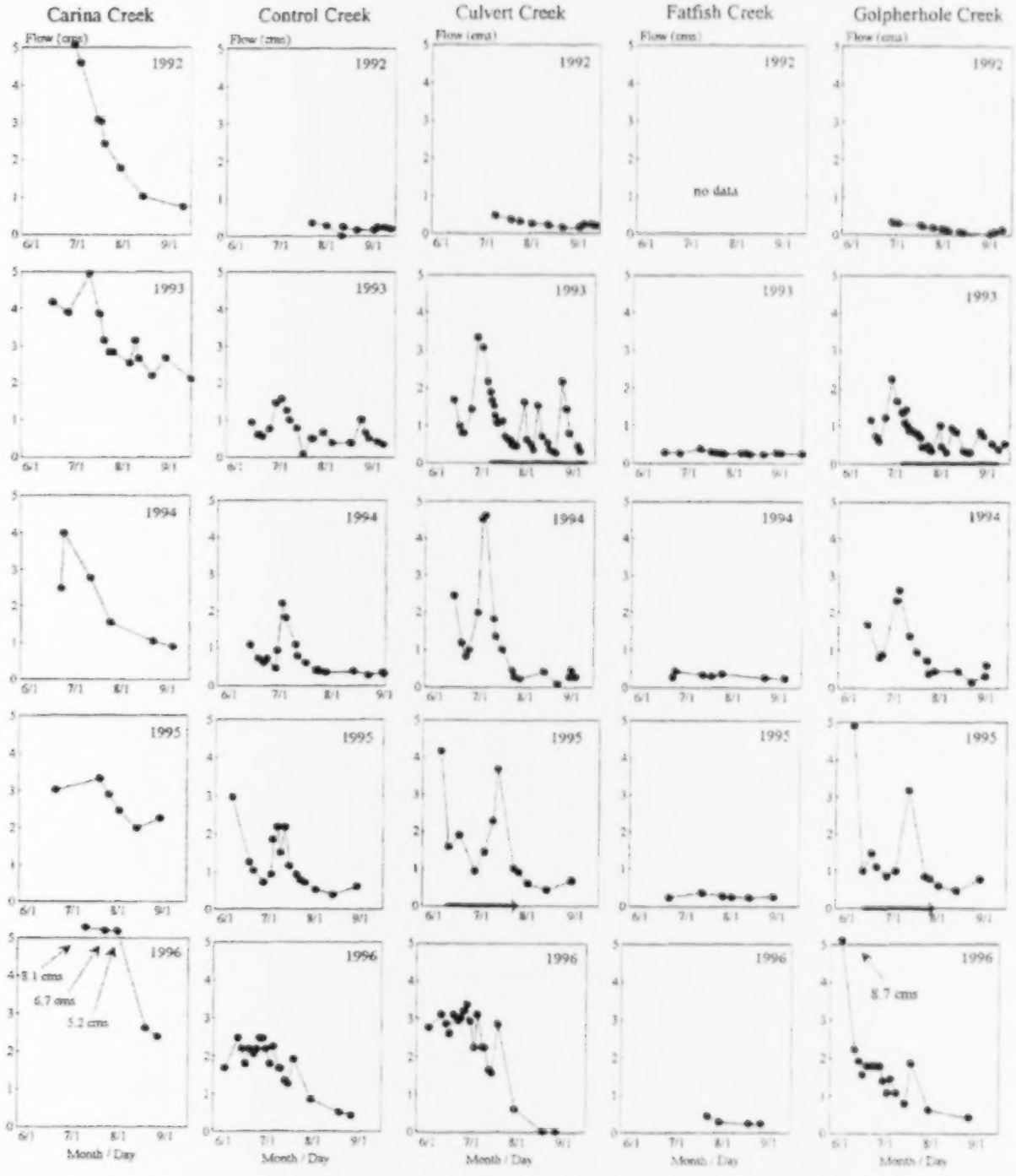

Figure 4. Discharge from tributaries of the Mesilinka River during summers of 1992-1996. Dark lines on x-axes of 1993 and 1995 Culvert and Gopherhole creeks indicate approximate time of 1993 liquid fertilizer addition, and dissolution of slow release briquettes in 1995.

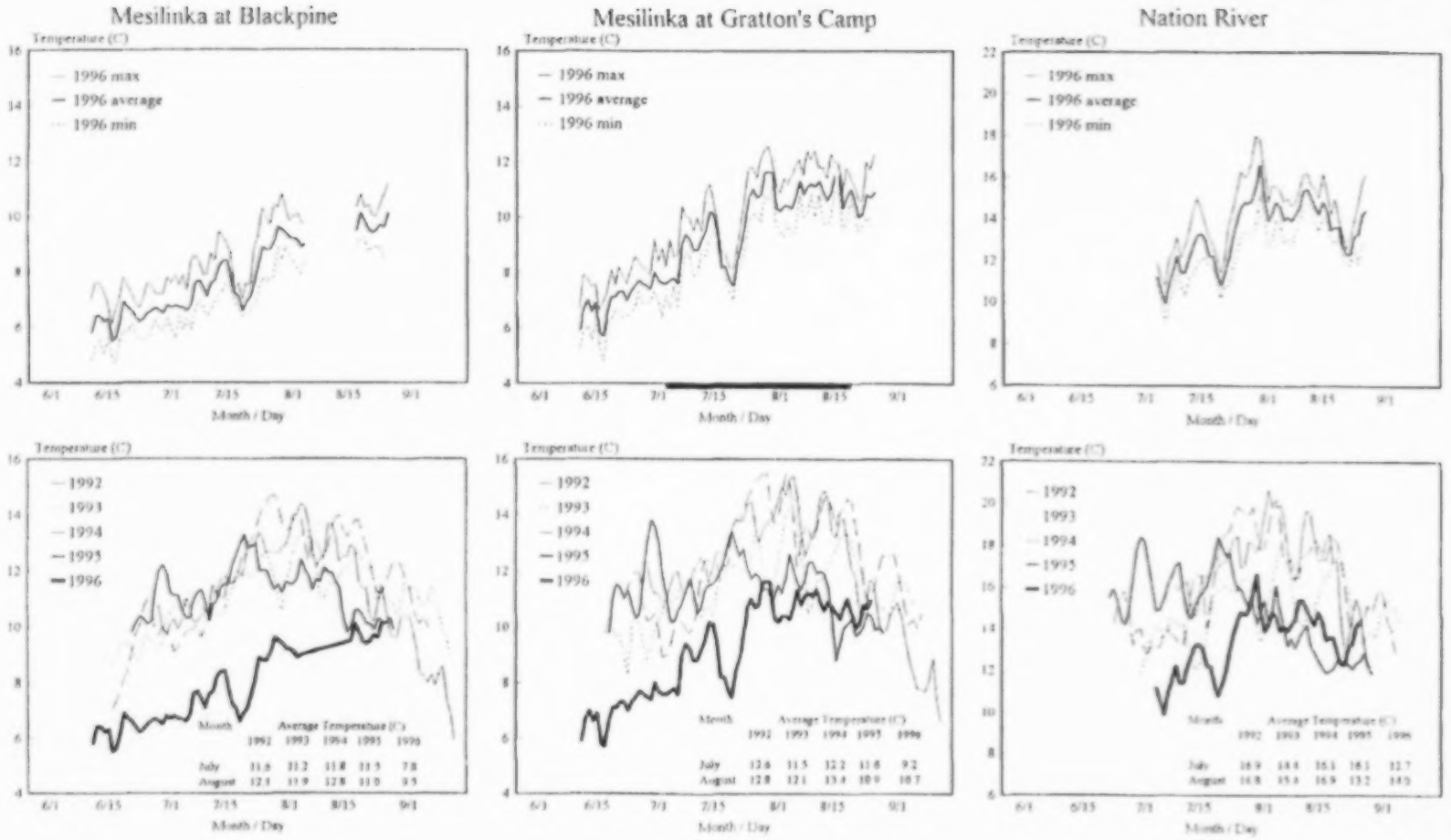

Figure 5. Mesilinka and Nation river water temperatures, 1992-1996. Dark line on x-axis of Gratton's Camp graph indicates time of 1996 liquid fertilizer addition.

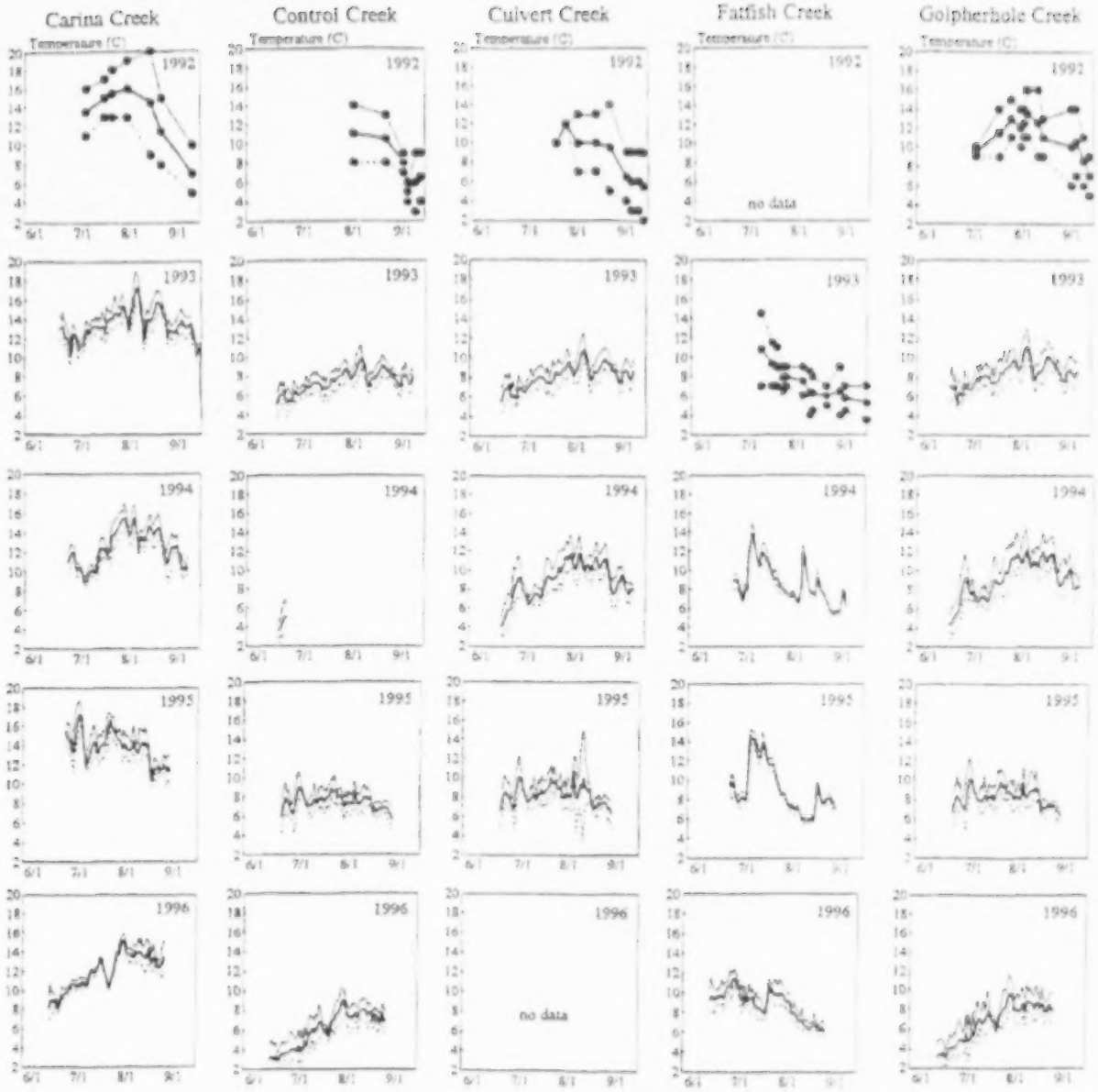

Figure 6. Mesilinka River tributary water temperatures, 1992-1996. Dark lines on x-axes of 1993 and 1995 Culvert and Gopherhole creeks indicate approximate time of 1993 liquid fertilizer addition, and dissolution of slow release briquettes in 1995.

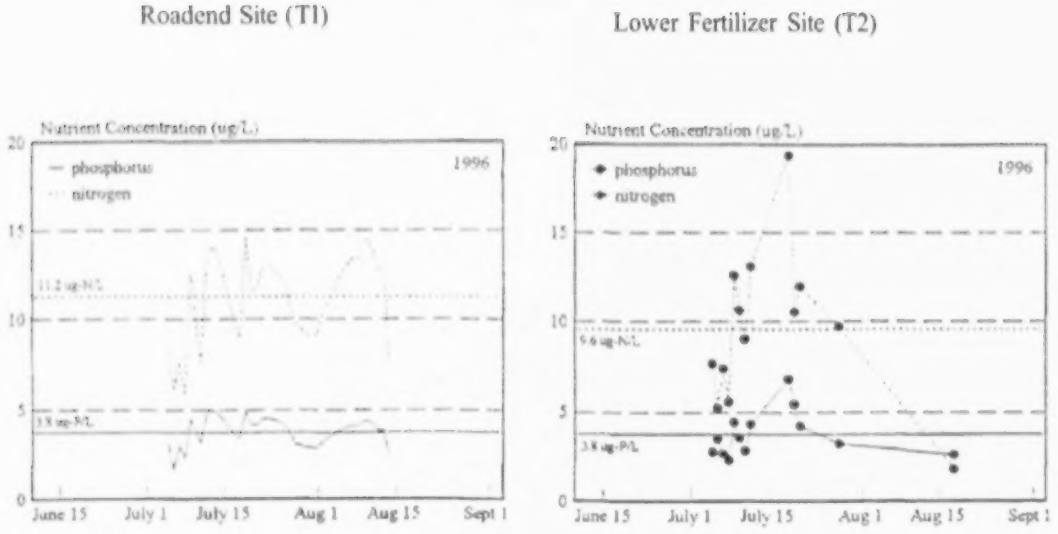

Figure 7. Estimated daily loading rates of fertilizer (nitrogen and phosphorus) added to the Mesilinka River at the Roadend and Lower Fertilizer sites during 1996.

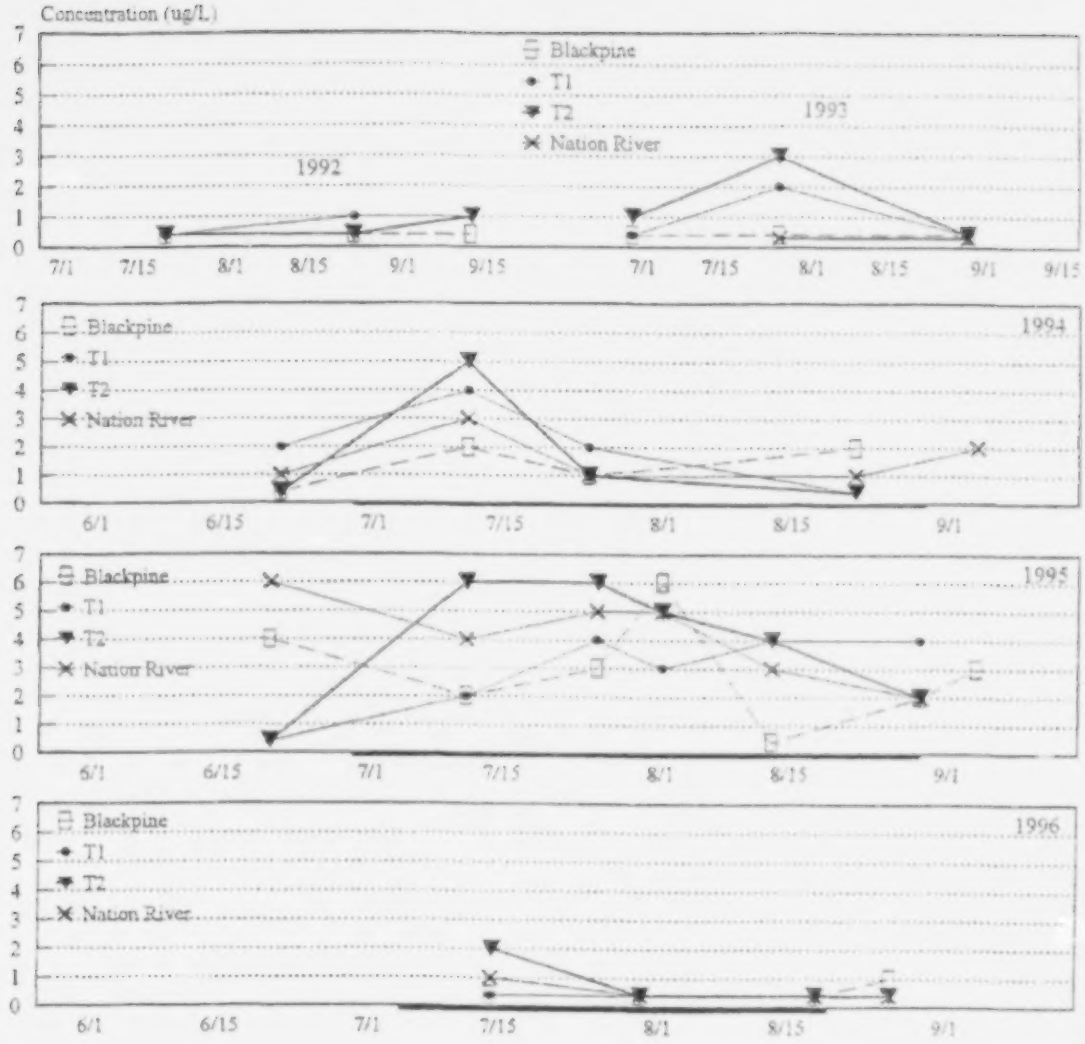

Figure 8. Soluble reactive phosphorous (SRP) concentration measured in the Mesilinka and Nation rivers, 1992-1996. Concentrations determined as below the analytical detection limit are shown at half the detection limit value of 1 $\mu g \cdot L^{-1}$. Dark lines on the x-axes indicate approximate time of liquid fertilizer addition to the T1 and T2 reaches.

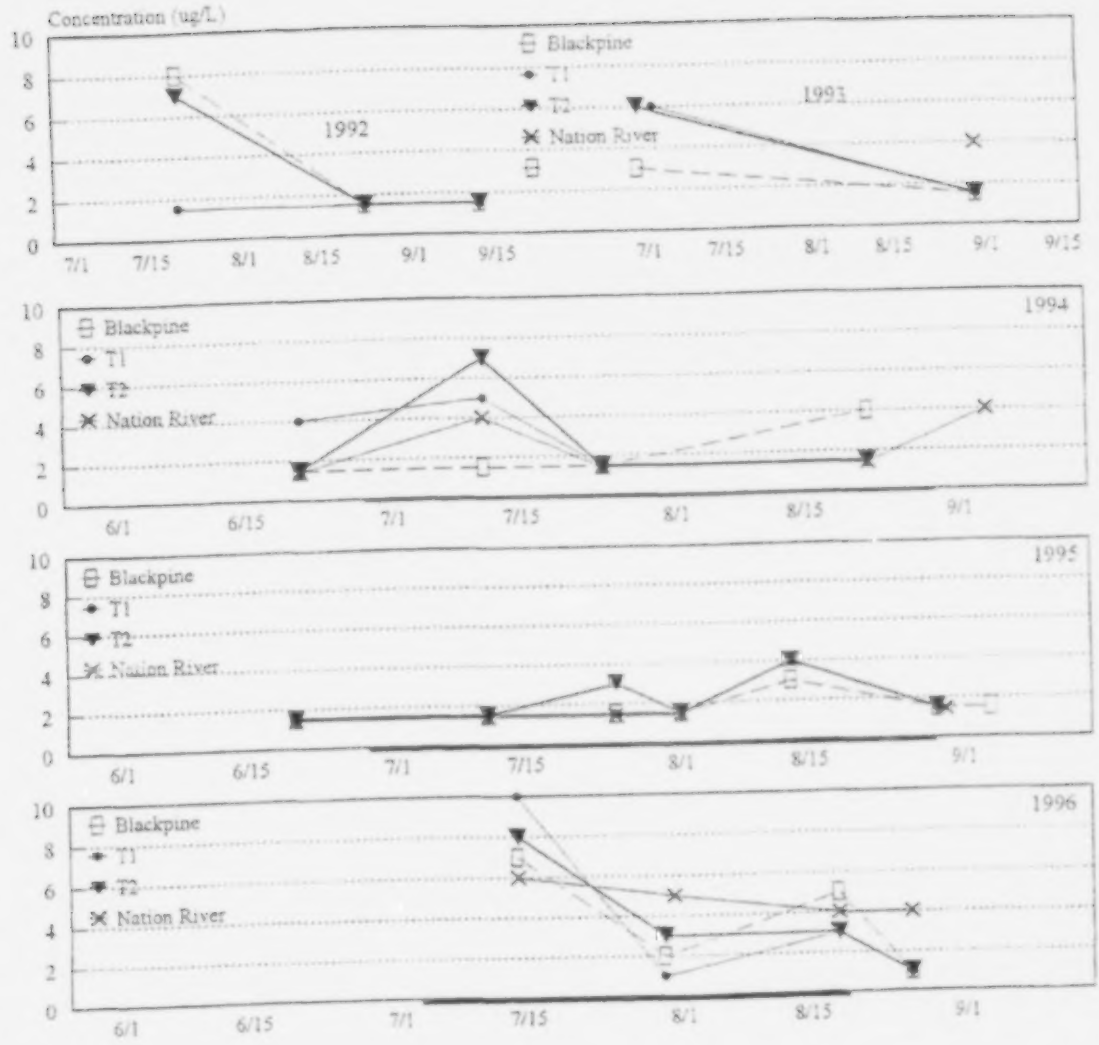

Figure 9. Total dissolved phosphorous (TDP) concentration measured in the Mesilinka and Nation rivers, 1992-1996. Concentrations determined as below the analytical detection limit are shown at half the detection limit value of 3 $\mu g \cdot L^{-1}$ for 1992-1995 data, and 2 $\mu g \cdot L^{-1}$ for 1996 data. Dark lines on the x-axes indicate approximate time of liquid fertilizer addition to the T1 and T2 reaches.

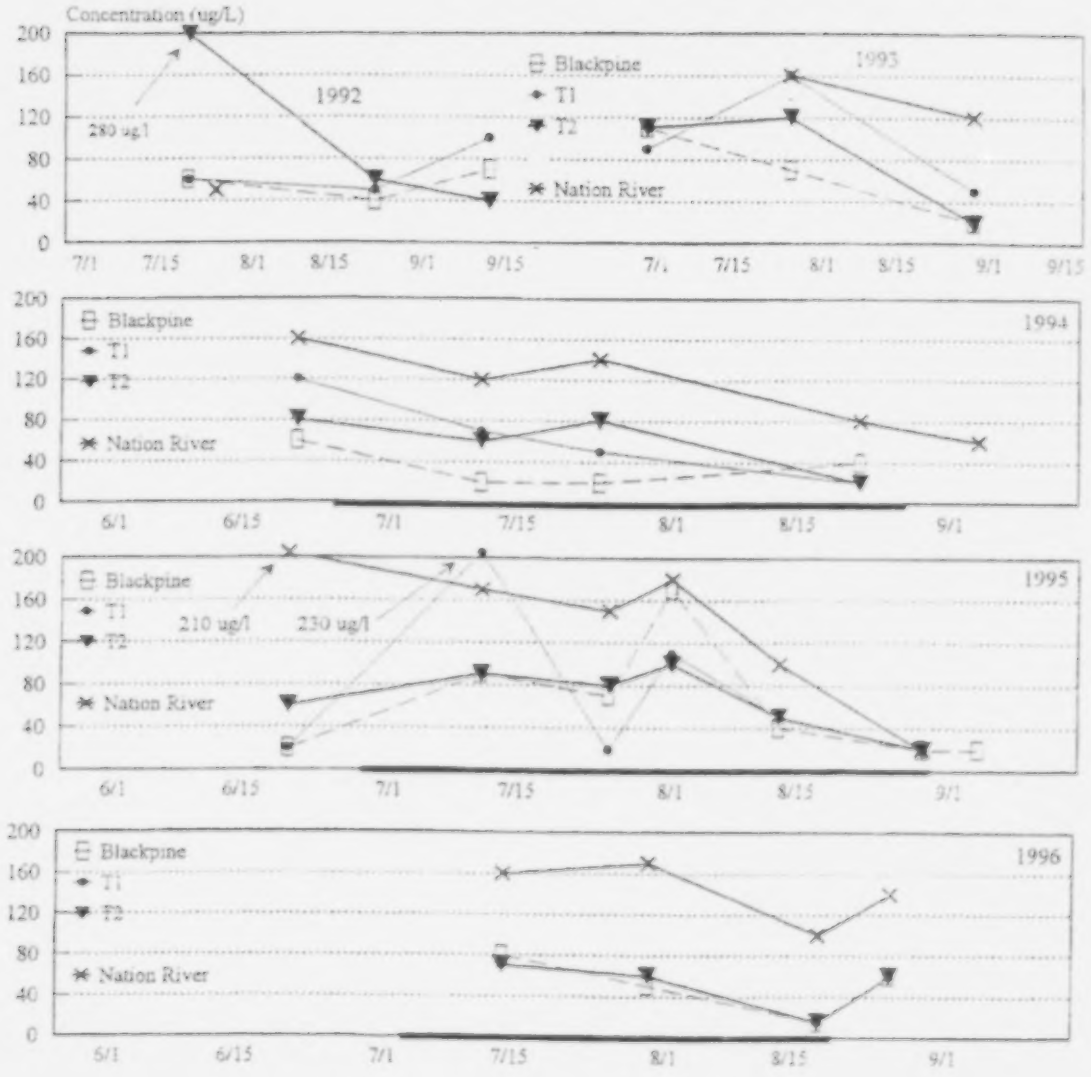

Figure 10. Total organic nitrogen (TON) concentration measured in the Mesilinka and Nation rivers, 1992-1996. Concentrations determined as below the analytical detection limit are shown at half the detection limit value of 40 $\mu g \cdot L^{-1}$. Dark lines on the x-axes indicate approximate time of liquid fertilizer addition to the T1 and T2 reaches.

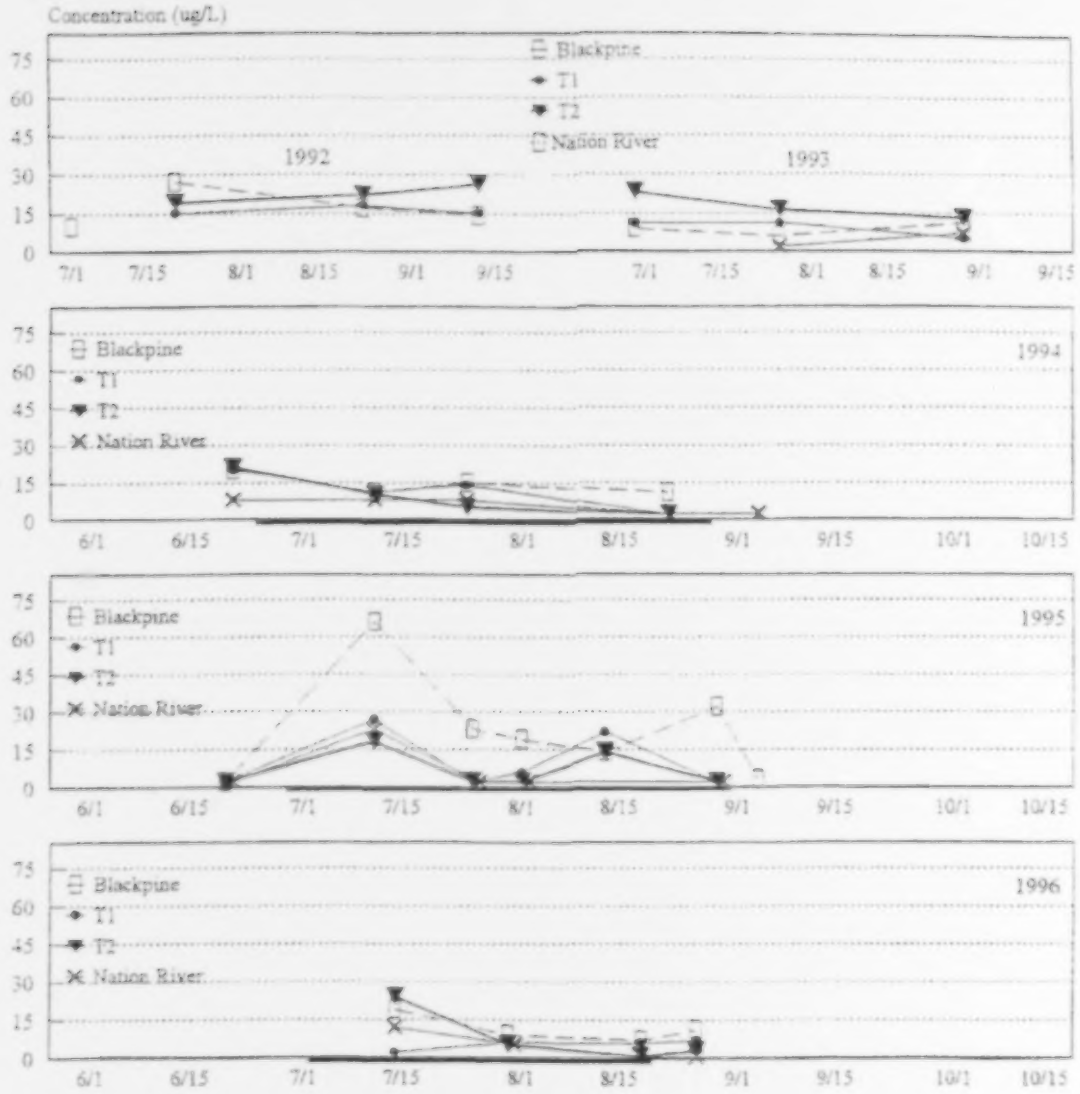

Figure 11. Nitrate and nitrite nitrogen (NO_3+NO_2-N) concentration measured in the Mesilinka and Nation rivers, 1992-1996. Concentrations determined as below the analytical detection limit are shown at half the detection limit value of 5 $\mu g \cdot L^{-1}$ for 1992-1995 data, and 2 $\mu g \cdot L^{-1}$ for 1996 data. Dark lines on the x-axes indicate approximate time of liquid fertilizer addition to the T1 and T2 reaches.

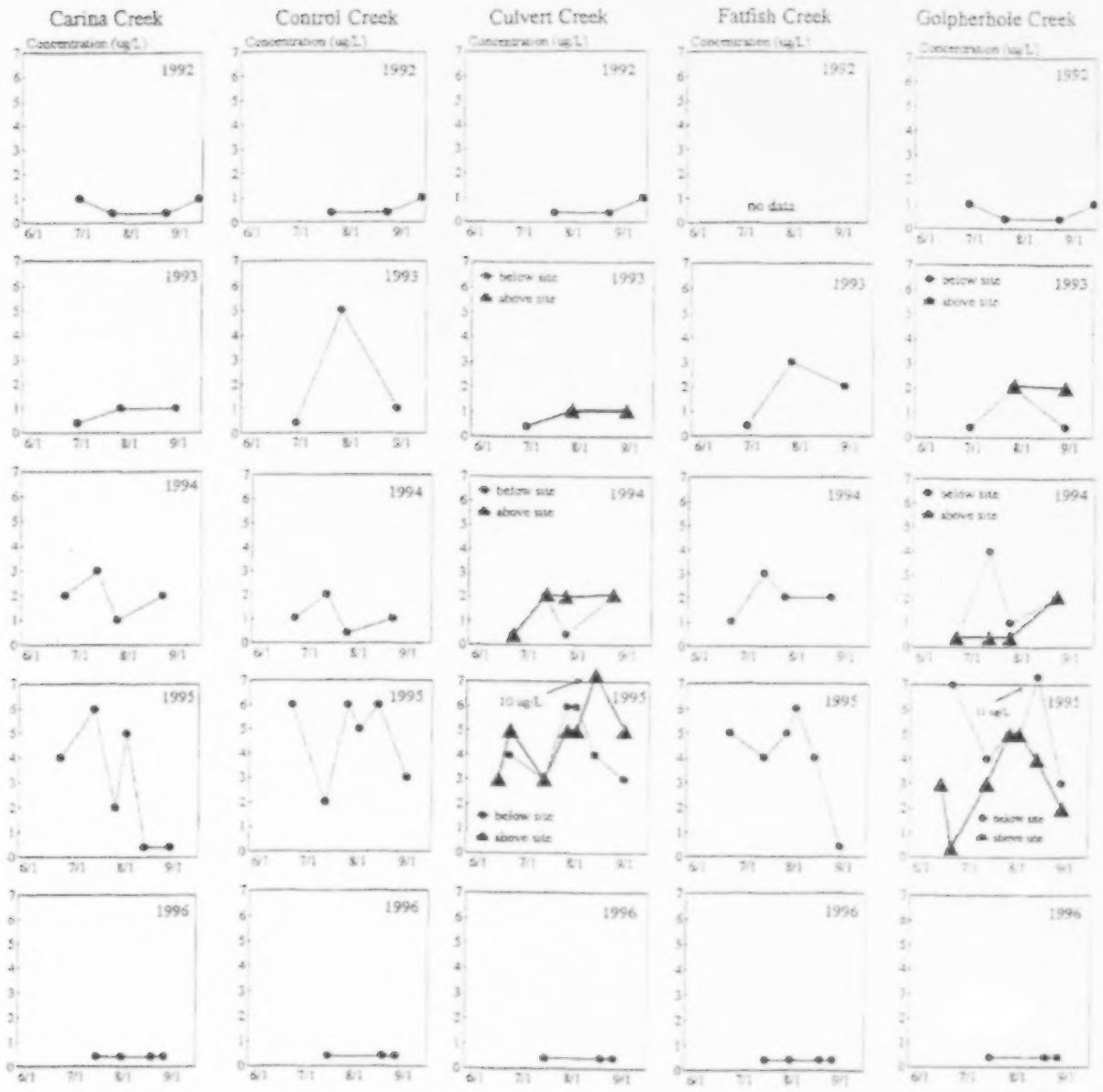

Figure 13. Soluble reactive phosphorous (SRP) concentration measured in Mesilinka River tributaries, 1992-1996. Dark lines on x-axes of 1993 and 1995 Culvert and Gopherhole creeks indicate approximate time of 1993 liquid fertilizer addition, and dissolution of slow release briquettes in 1995. Concentrations determined as below the analytical detection limit are shown at half the detection limit value of 1 $\mu g \cdot L^{-1}$.

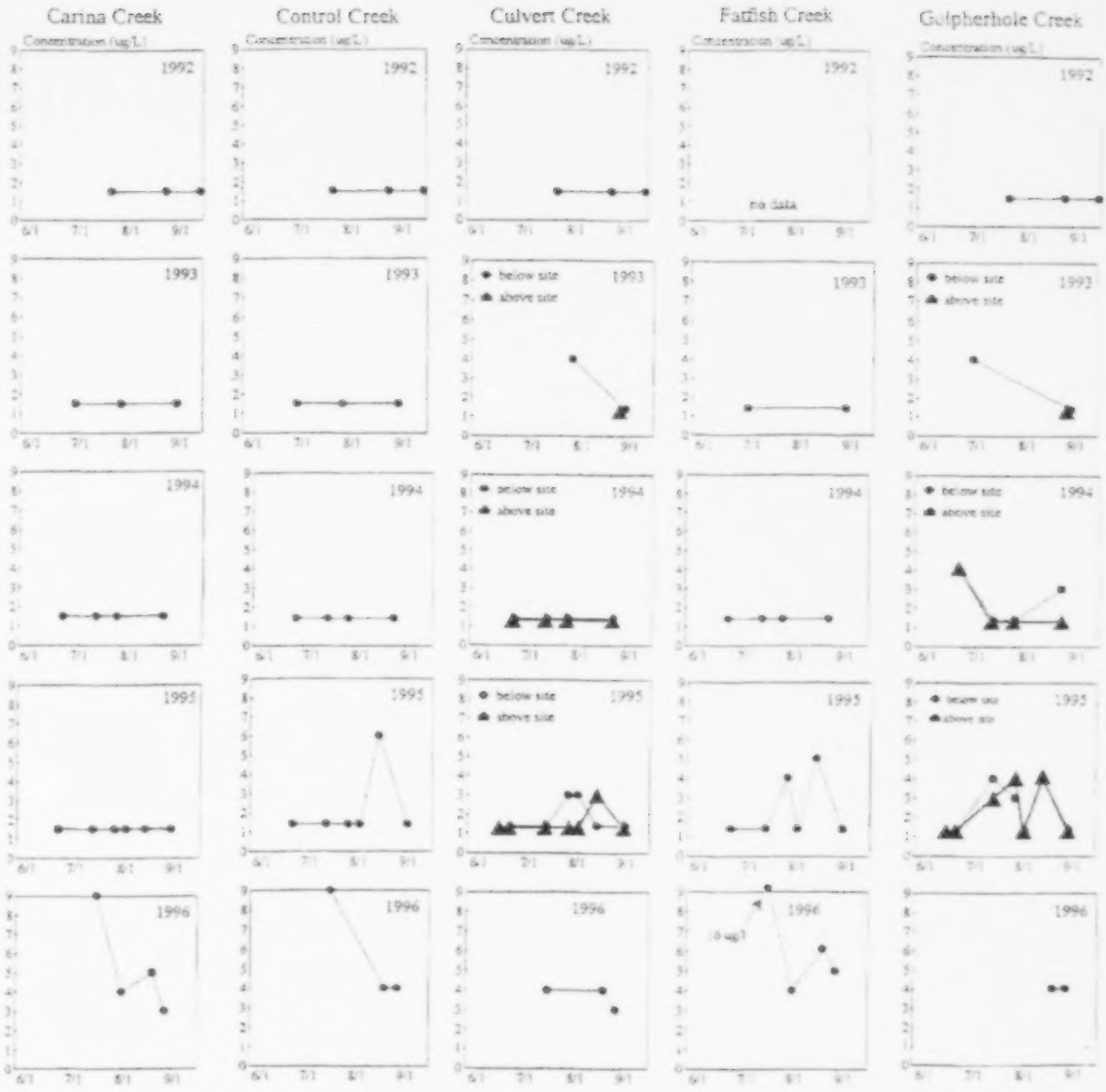

Figure 14. Total dissolved phosphorous (TDP) concentration measured in Mesilinka River tributaries, 1992-1996. Dark lines on *x-axes of* 1993 and 1995 Culvert and Gopherhole creeks indicate approximate time of 1993 liquid fertilizer addition, and dissolution of slow release briquettes in 1995. Concentrations determined as below the analytical detection limit are shown at half the detection limit value of 3 $\mu g \cdot L^{-1}$ for 1992-1995 data, and 2 $\mu g \cdot L^{-1}$ for 1996 data.

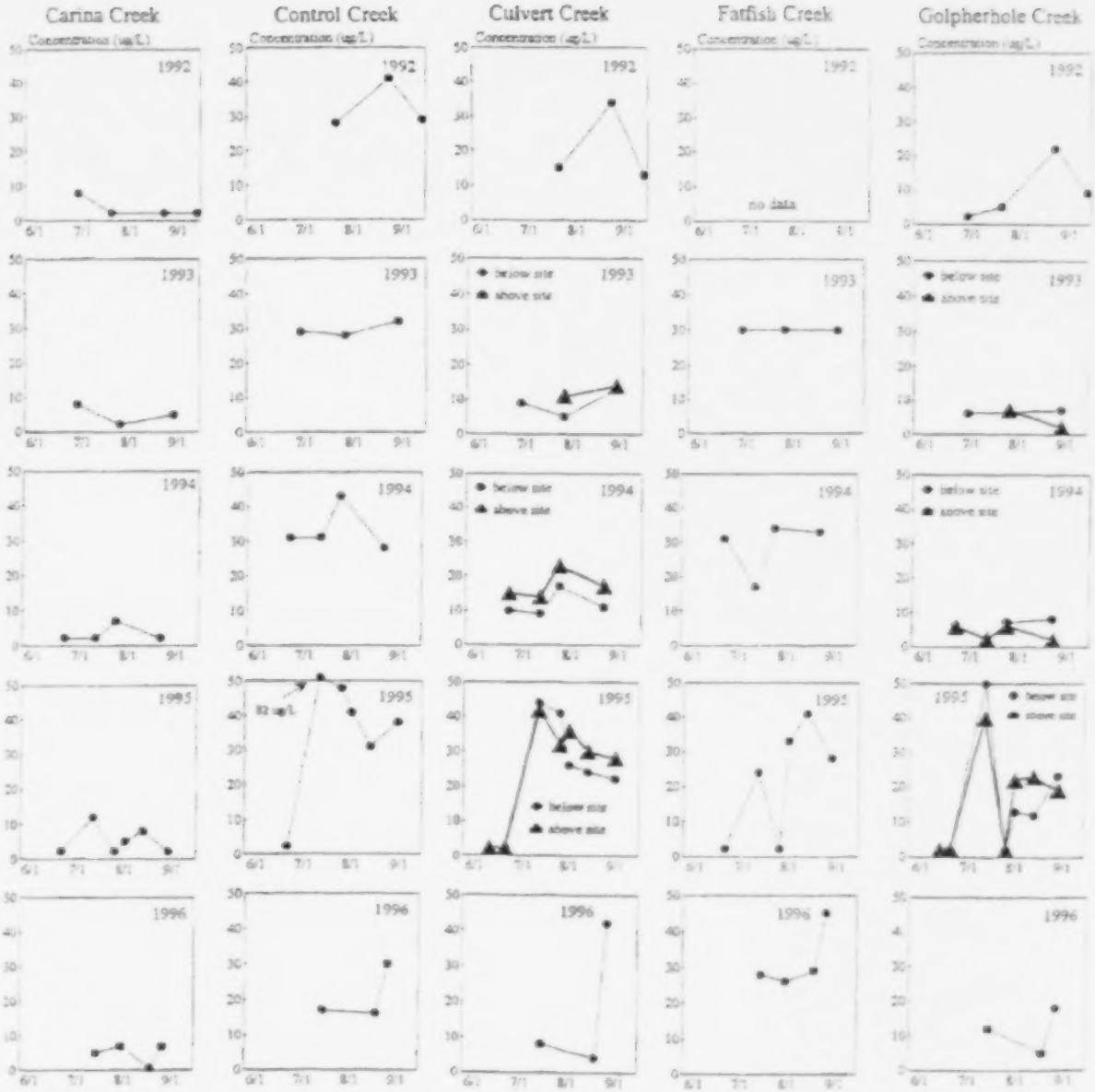

Figure 15. Nitrate and nitrite nitrogen (NO_3+NO_2-N) concentration measured in Mesilinka River tributaries, 1992-1996. Dark lines on x-axes of 1993 and 1995 Culvert and Gopherhole creeks indicate approximate time of 1993 liquid fertilizer addition, and dissolution of slow release briquettes in 1995.

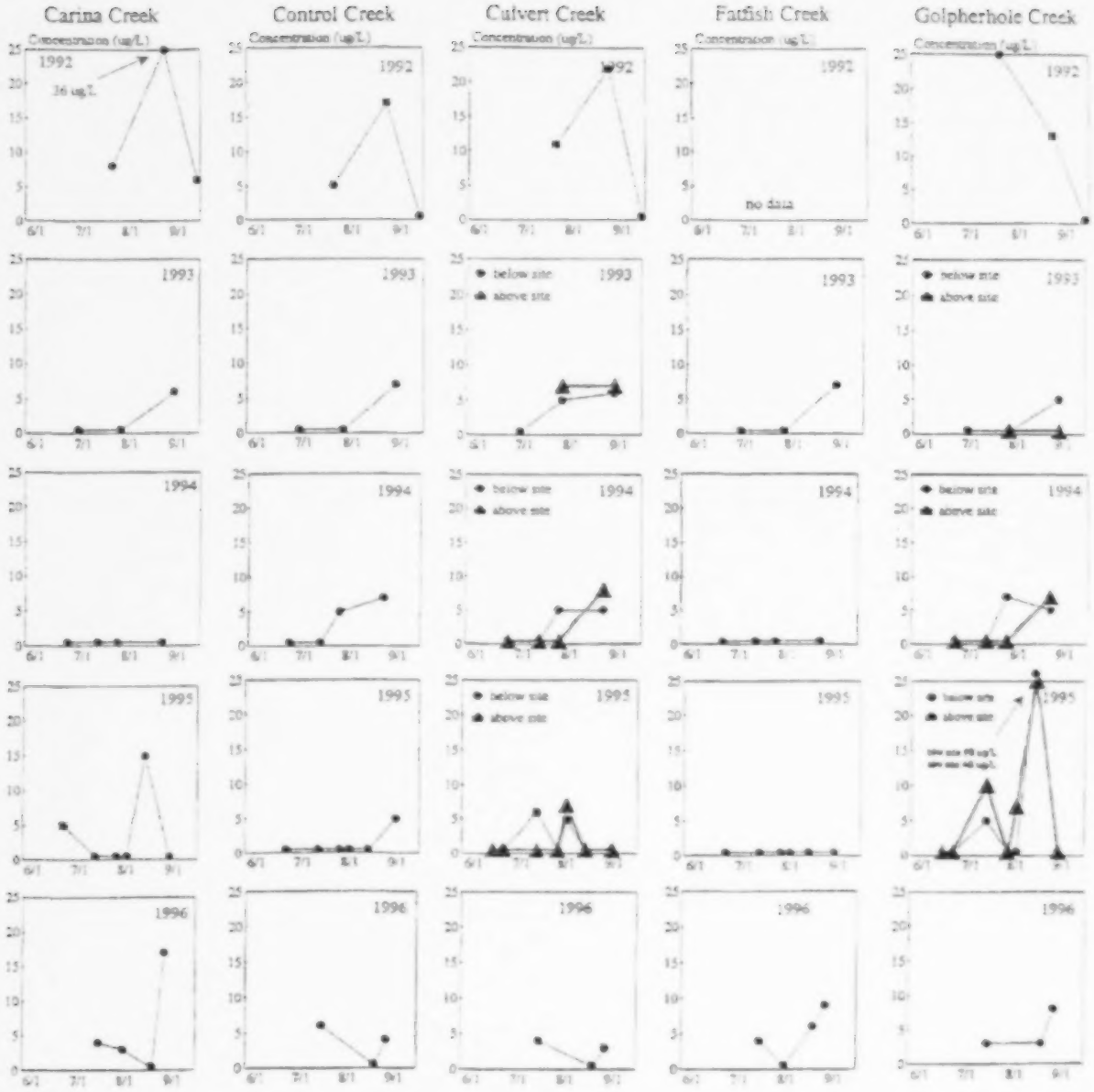

Figure 16. Ammonia nitrogen (NH_3-N) concentration measured in Mesilinka River tributaries, 1992-1996. Dark lines on x-axes of 1993 and 1995 Culvert and Gopherhole creeks indicate approximate time of 1993 liquid fertilizer addition, and dissolution of slow release briquettes in 1995. Concentrations determined as below the analytical detection limit are shown at half the detection limit value of 5 $\mu g \cdot L^{-1}$ for 1992-1995 data, and 2 $\mu g \cdot L^{-1}$ for 1996 data.

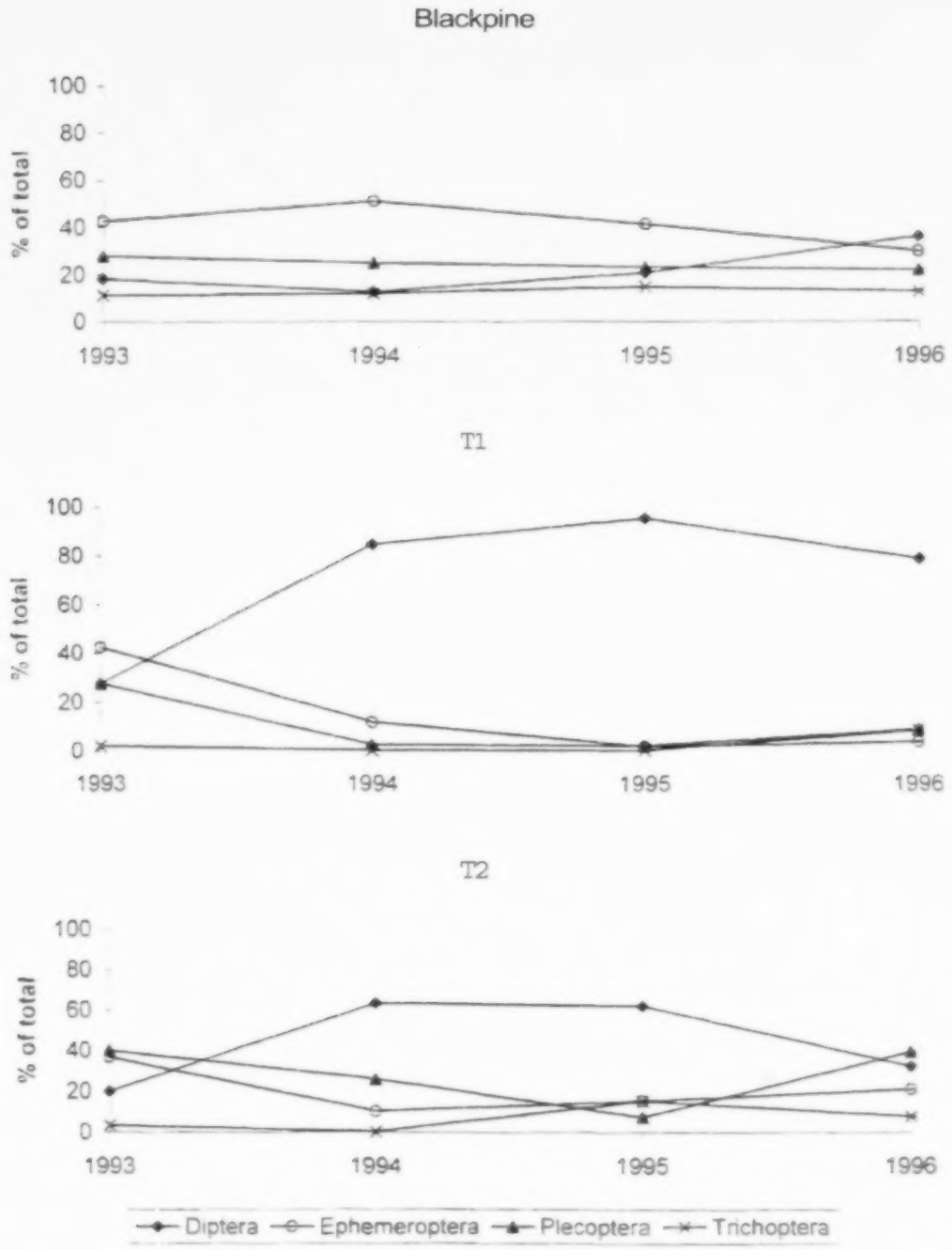

Figure 17. Relative abundance of four taxonomic groups of benthic invertebrates in the Mesilinka River, 1992-1996.

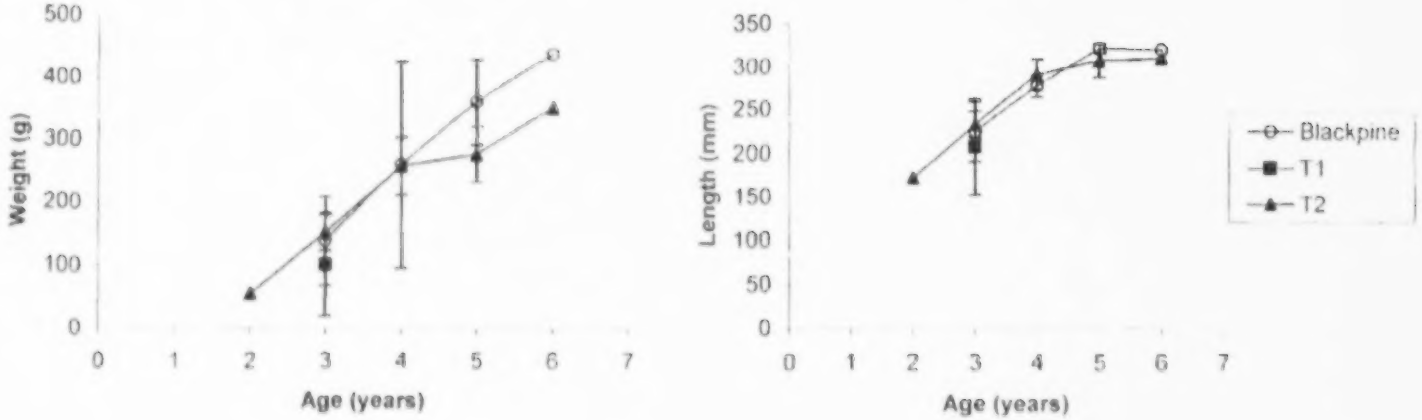

Figure 18. Weight-at-age and length-at-age for Mesilinka River rainbow trout captured by angling in 1996. Error bars are 2 standard errors of the mean.

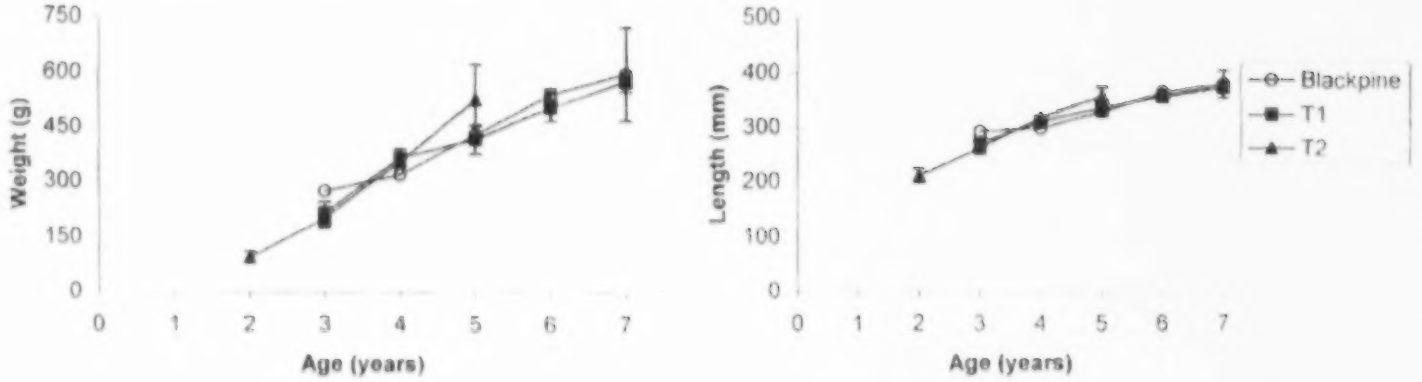

Figure 19. Weight-at-age and length-at-age for Mesilinka River Arctic grayling captured by angling in 1996. Error bars are 2 standard errors of the mean.

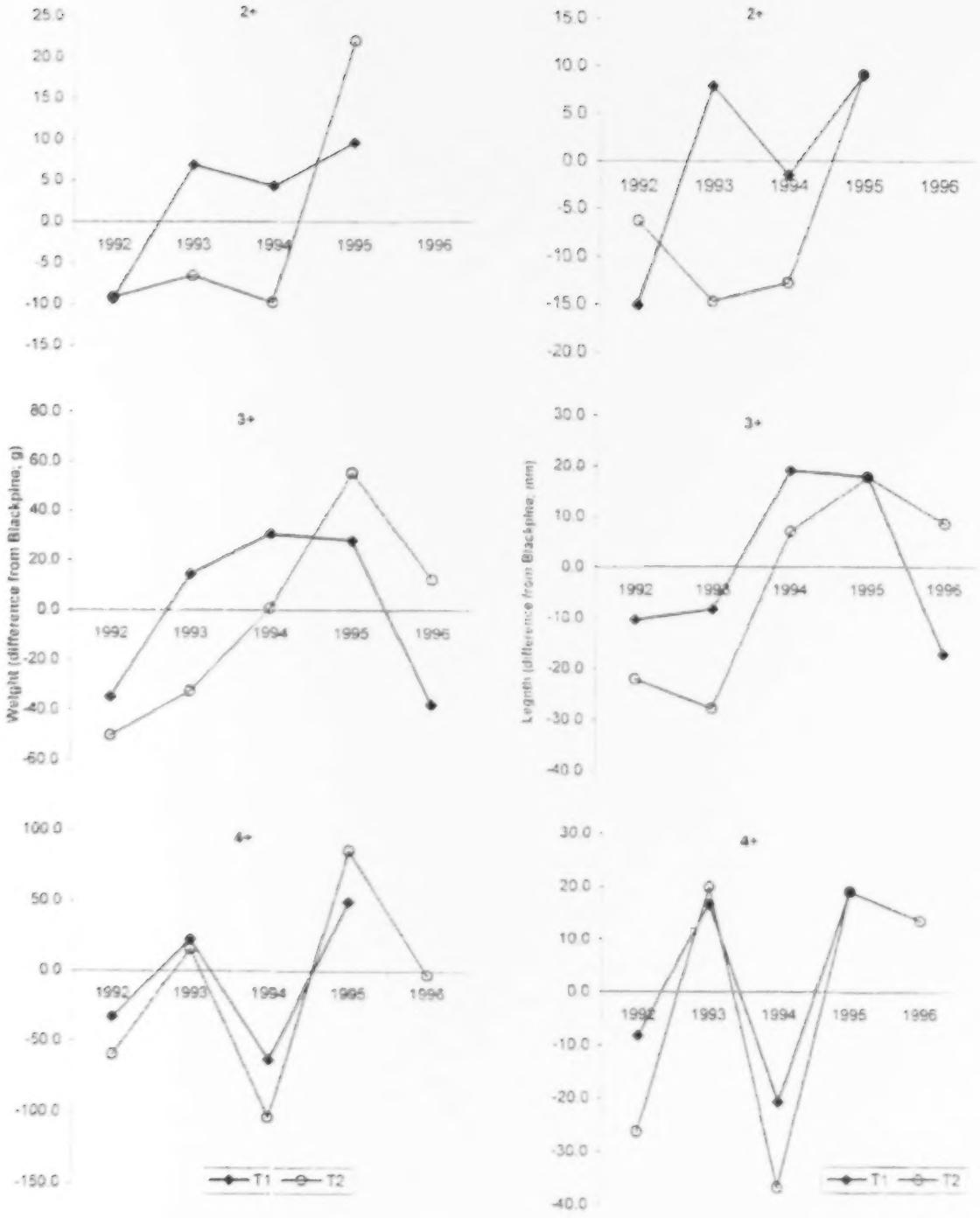

Figure 20. Responses of 2+, 3+ and 4+ rainbow trout to fertilization in the T1 and T2 reaches of the Mesilinka River, presented as differences from the Blackpine (control) reach.

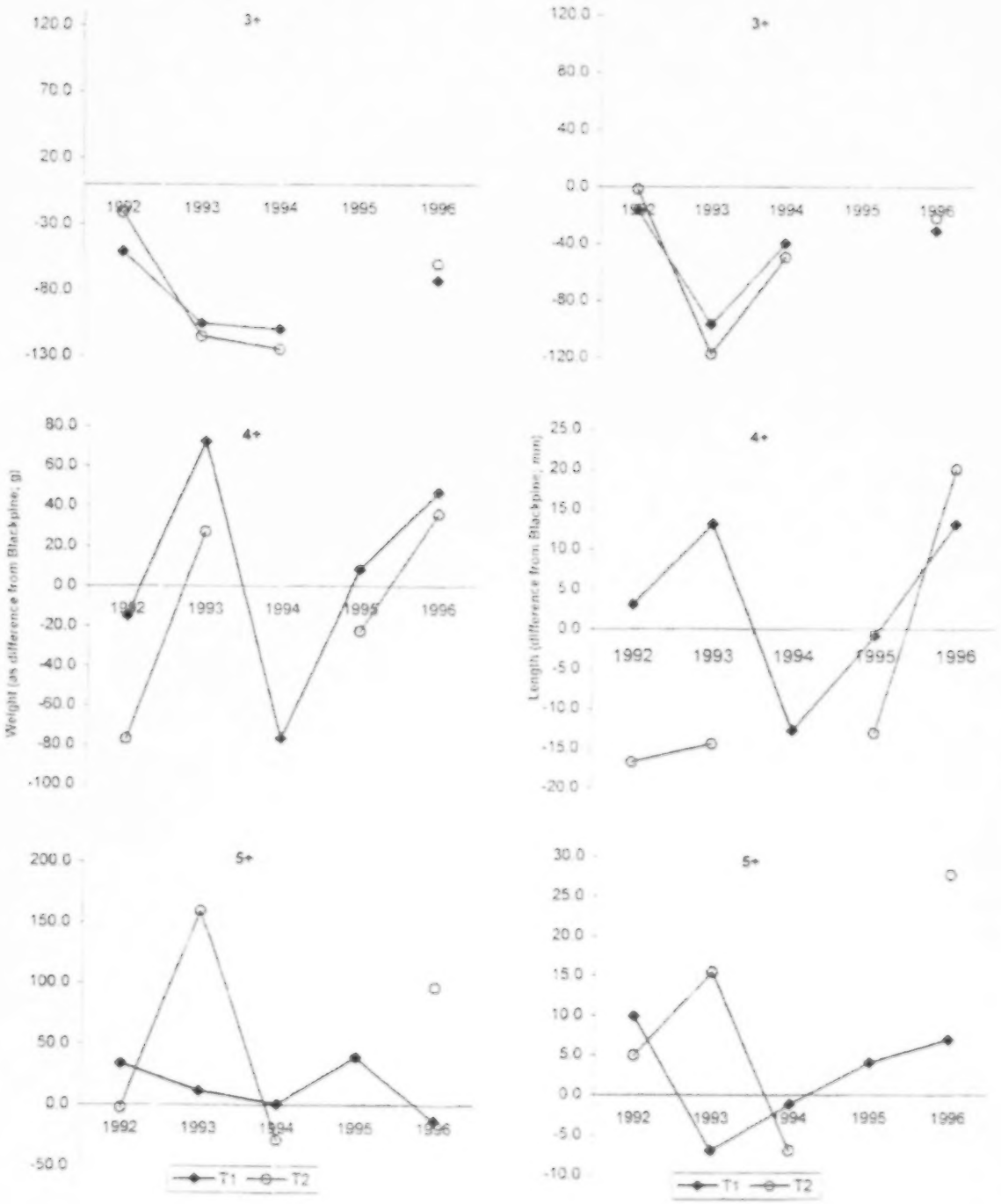

Figure 21. Responses of 3+, 4+ and 5+ Arctic grayling to fertilization in the T1 and T2 reaches of the Mesilinka River, presented as differences from the Blackpine (control) reach.

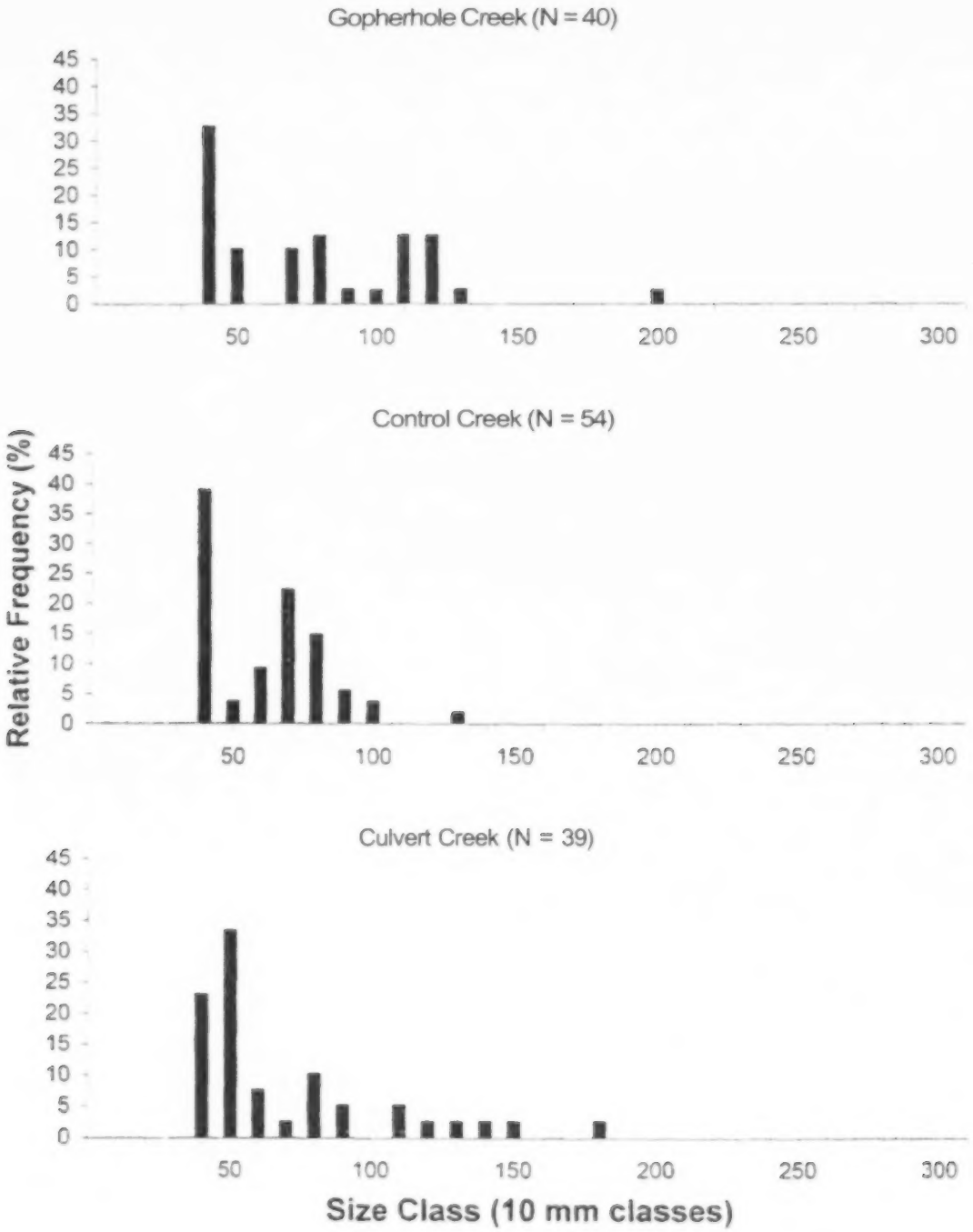

Figure 22. Length-frequency plots for all bull trout captured in three tributaries of the Mesilinka River, 1996.